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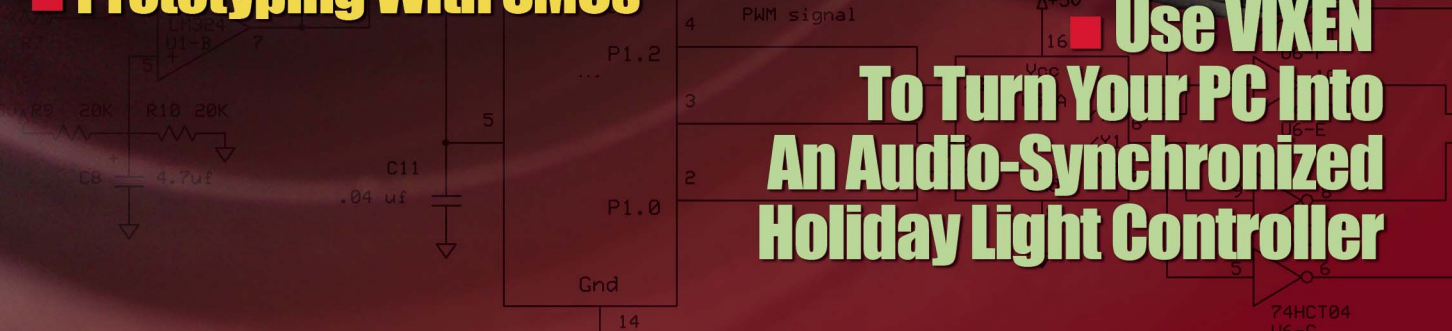
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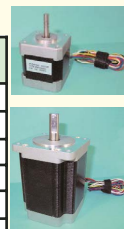
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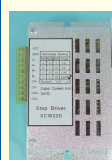
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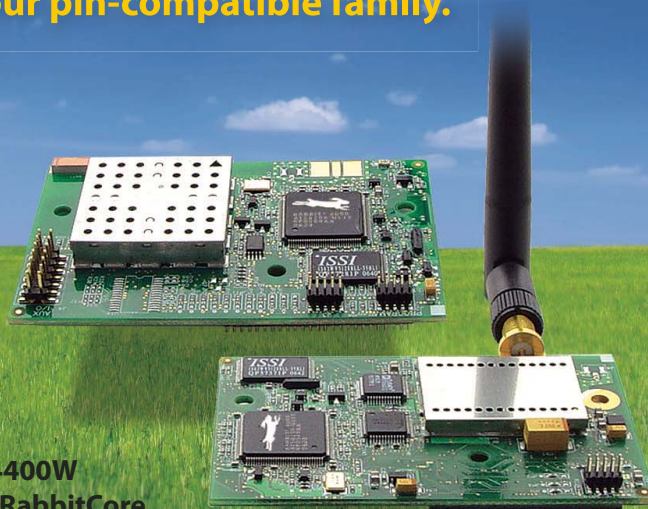
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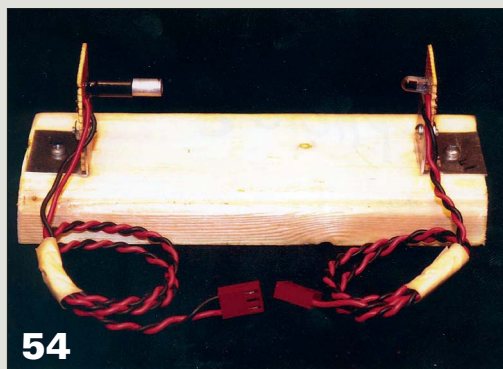
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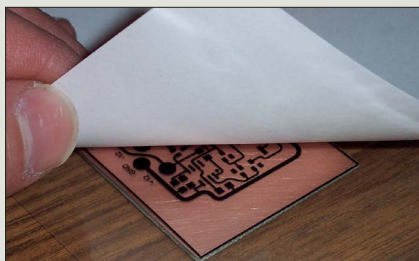
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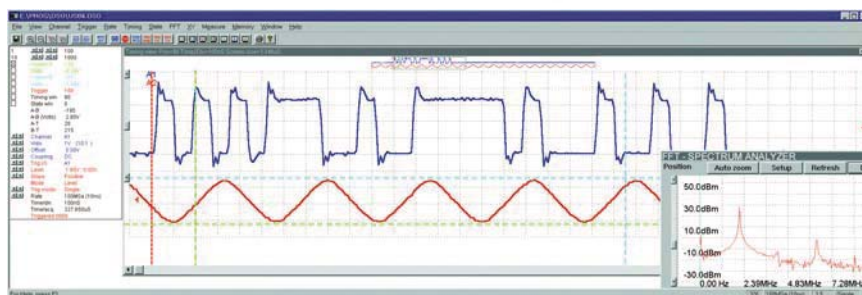
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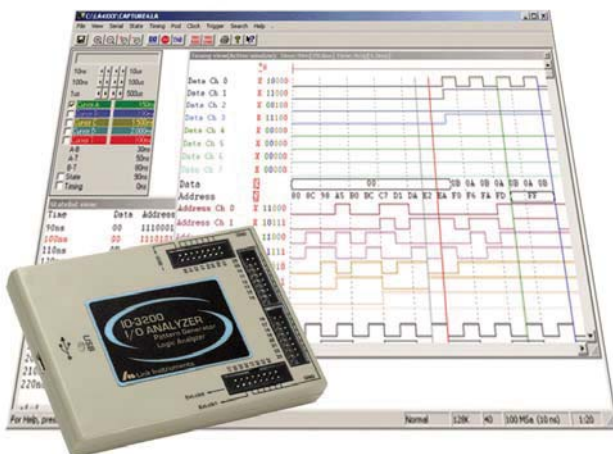
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by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

An electric musical instrument shop is a dangerous place if you're an electronics enthusiast with a charge card — even if you can't play a riff on a guitar. The modern, plugged-in musician isn't limited to guitars, drums, microphones, keyboards, and other personal instruments, but is adept with a variety of 'control surfaces' — MIDI controller keyboards, mixers, faderports, and the like. Moreover, they are at home with computer-based sequencers, hardware- and firmware-based signal processors, and a seemingly endless supply of preamps, amplifiers, and support peripherals. I have yet to enter a fully stocked music store and not discover a device or software package that I didn't even know existed.

The primary driver behind the increasingly sophisticated electronic face of music is economics. It simply costs more to assemble a classic studio than one composed of digital gear, including a desktop or laptop computer. Another driver is simply the fun factor. There's more room for free expression and experimentation with digital gear than with single-dimension traditional instruments. After all, why limit yourself to solos

when you can play with and direct a virtual band? A third driver is the increasing popularity of podcasts and youtube. The desire to author content for these and similar services has ignited interest in the mainstream technology community in high-quality, affordable USB microphones, preamplifiers with digital output, sequencers, and post-production hardware and software.

Full-featured sequencers, exemplified by Cakewalk Project5 for Windows and Logic Studio and GarageBand for OS X, enable you to create, record, edit, and mix music from the comfort of a keyboard. Given a modest understanding of music theory, why learn to play the drums or sax when you can simply select a virtual instrument from a drop-down menu? In addition to computer-based tools, there is a staggering array of stand-alone electronic devices. For example, most electric guitarists wouldn't consider playing without some kind of effects processor that not only adds special effects such as reverb, echo, or delay to a sound, but that can model the audio characteristics of guitars, amplifiers, and even the instruments used by specific artists.

Two of my favorite low-end effects processors are represented by the pocketPOD from Line 6 (see Figure 1) and the Micro Cube combination amp-effects processor from Roland. Both units are entry-level products with a street price of about \$130. Although you can easily spend thousands for a high-end amp or processor, products in the \$100-\$200 range are perfectly suitable for home or amateur band use. With the Micro Cube amp, I can make my Gibson Melody Maker sound like a traditional acoustic guitar or add flanger or phaser effects to approximate the sounds of the guitar-amplifier combinations used in my favorite rock bands. What the battery-powered unit the size of a bookshelf speaker lacks in power and repertoire of effects is offset by ease of use and portability. Of course, even the best effects processor won't give you the skill of a professional guitarist — that takes years of practice.

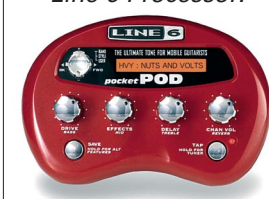
The pocketPOD — which is inserted inline between the guitar and preamp — is an impressive effects processor in a portable package. The pocketPOD is based on the Freescale 56364 DSP chip, which provides the unit with 24 bits of dynamic range and 100 MIPS of processing power. All that power means that you can model over 300 vintage and modern guitars and amplifiers. Additional models or presets can be downloaded from the Line 6 website and uploaded into the pocketPOD via its USB port.

Roland and Line 6 are but two of dozens of brands of guitar effects processors. And we haven't even considered drum machines, wind instrument controllers, multi-track recorders, studio monitors, or tuners. For the latest developments in electronic music technology, a good source is Electronic Musician. Of course, nothing beats hands-on experimentation at your local music store. Just make sure to leave your charge card at home. **NV**

RESOURCES:

- Apple Logic Studio www.apple.com
- Cakewalk Project5 www.cakewalk.com/products/Project5/sequence.asp
- Line 6 Processor www.line6.com
- Roland Micro Cube www.roland.com
- Electronic Musician emusician.com

FIGURE 1.
Line 6 Processor.



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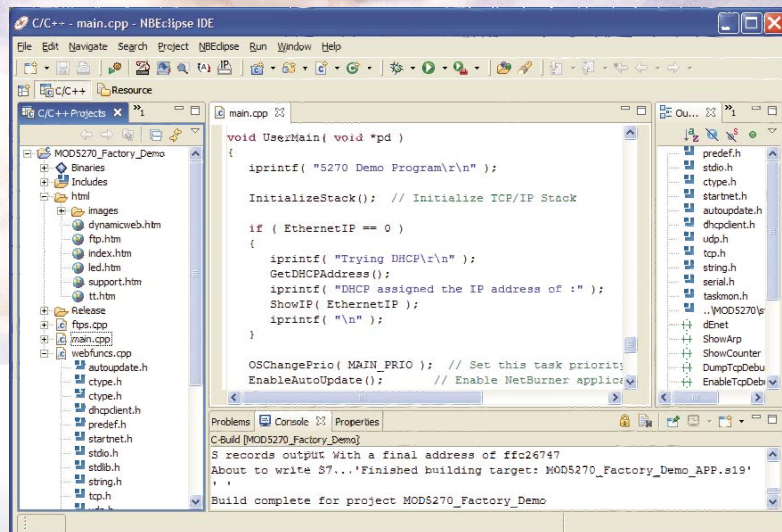
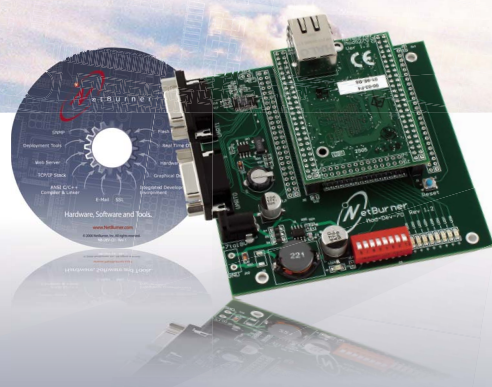


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FAB ON FUSION

I enjoyed Jeff Eckert's note on Sandia's progress toward fusion. I also get the Sandia bulletin (I forget the name), and I am impressed with what a good job the people there do.

I was struck by the "as little as two decades away" at the end of Eckert's excellent summary. When I interviewed at the Forestall labs (Stellarator) in 1956, as I recall, they were only 20 years away, and I told them they wouldn't even get there then if they didn't hire me — they didn't on both counts. And when I visited ORNL's DX2 in 1956, they were confident they were very close to breaking even. I think mirror leakage killed them and then they modified the containment to the Russian system — I forget the name, and I don't know what happened to the project after that.

I do hope the Sandia project reaches practicality for a variety of reasons (such as up LANL's nose and a much needed source of electrical energy).

Thanks for your reviews; I always enjoy them.

E.G. (Jerry) Bylander



PARTS PARADOX

I have been struggling to build the ".01% ACCURATE VOLTAGE REFERENCE" as designed by Doug Malone on page 52 of the September '07 issue.

My problem is that the specification for D3, an LM431CCZX variable zener diode, while an accurate number, is unavailable anywhere I can find (Mouser, Digi-Key, Avnet, etc.), and Fairchild (the manufacturer) has none in stock. They are postponing delivery of two pieces every 30 days for another 30 days.

I need to find out where these diodes can be bought, or more importantly, if there is an acceptable substitute.

As a long time subscriber, thanks for any help you can supply.

Norman Sheldon K0JUP

Response: I find it challenging to specify readily available components when an article is written and have them continue to remain available when a subscriber attempts to obtain the parts. Fortunately, in this case, there are substitutes that are in stock at two suppliers: Mouser# 511-TL1431CZ; Digikey # LM431CCZ.

Alas, there is another part in the design — the X60008 — that is becoming more difficult to obtain. I have parts available and can also refer interested readers towards other sources.

Doug Malone
dmalone@pacifier.com

Continued on page 95

WHO'S THE BOSS?

Datasheet Summary for monthly columnist Fred Eady's newest grandchild:

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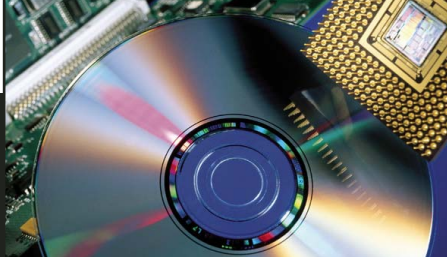
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■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

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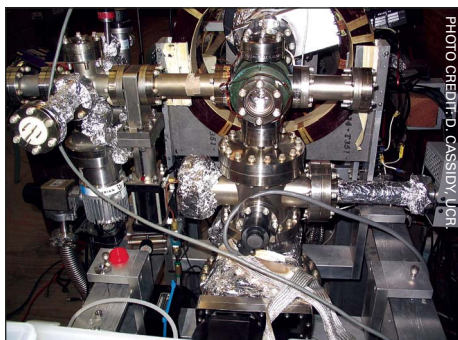


PHOTO CREDIT: D. CASSIDY, UCR

■ The ultra-high vacuum target chamber, where the intense positron pulse is implanted into porous silica film.

In case you're not up on particle physics, note that when an electron meets its antimatter counterpart — the positron — this generally results in mutual annihilation and the release of a couple gamma rays. But occasionally, a hydrogen-like atom — with the proton replaced by the positron — may be formed and exist for something like 0.1 ns in the form of positronium (Ps).

Physicists tell us that about 15 billion tons of positrons are annihilated every second in the Milky Way bulge, so there must be quite a bit of it around. However, until recently, no one had created it in a lab. Enter Prof. Allen Mills and researcher David Cassidy, of the University of California, Riverside (www.ucr.edu), who have done exactly that by firing intense bursts of positrons into a thin film of porous silica, which catches them like a cage, slows down the process, and makes the Ps atom temporarily stable.

According to Cassidy, "This is the first step in our experiments. What we hope to achieve next is to get many more of the positronium atoms to interact simultaneously with one another — not just two positronium atoms at a time."

The concept may seem hopelessly

abstract, but the implications are fairly profound. Apparently, the creation of coherent gamma radiation could aid in the advancement of fusion power and, more dramatically, allow the creation of such weapons as gamma-ray lasers. The latter compared to today's lasers would be something like nuclear bombs compared to dynamite. The research was funded by the National Science Foundation, but the military is no doubt paying attention.

SUPERCONDUCTING COMPUTER CABLE

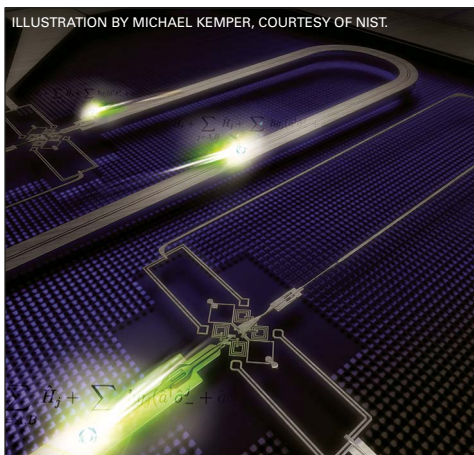


ILLUSTRATION BY MICHAEL KEMPER, COURTESY OF NIST.

■ Artist's rendition of the NIST superconducting quantum computing cable.

Quantum computers may be many years away, but someone has already figured out a way to connect their innards. Physicists at the National Institute of Standards and Technology (NIST, www.nist.gov) recently reported the successful transfer of information between two "artificial atoms" using electronic vibrations on microfabricated aluminum cable. It's sort of like CATV, only with no electrical resistance, plus multitasking data bits that operate under the rules of quantum physics. An advantage is that this type of connector may be easier to manufacture and scale up to a practical size than competing can-

didates, such as individual atoms.

Unlike the standard data bit, which holds only a 0 or 1 value, a quantum bit (qubit) can hold opposite values at the same time (superposition), much like a really tiny politician. This offers the possibility of exponentially faster computations. The resonant section of the NIST cable, known as a quantum bus, shuttles information between two or more qubits.

In the recent experiment, the scientists fabricated two qubits on a sapphire microchip and plunked them into an 8 cu. mm shielded box. The quantum bus was 7 mm long and zig-zagged round the 1.1 mm space between the qubits. Using the cable's ability to resonate at a particular frequency, the experimenters encoded information in one qubit, transferred it as microwave energy to the quantum bus for 10 ns, then transferred it to a second qubit. As an added benefit, the cable might also be used to transfer quantum information between matter and light.

AUTONOMOUS VEHICLE ENTERS FINAL TESTING



PHOTO COURTESY OF ADVANCED TRANSPORT SYSTEMS LTD.

■ The ULtra transportation system at the Cardiff trials site.

On a more practical level, the first full production version of the Urban Light Transport (ULtra) Personal Rapid Transit (PRT), from Advanced Transport Systems Ltd. (ATS, www.atsltd.co.uk), has been delivered to the Cardiff (Wales) trials site for commis-

sioning tests before implementation at the U.K.'s Heathrow Airport. The latest version of the vehicle features a more powerful motor, full climate control, and a complete passenger interface.

In the background of the photo, you can see the enhanced trials site, which replicates both the Car Park and Terminal stations at Heathrow and thus enables tests that match the anticipated actual vehicle duty cycle. Initial endurance trials of engineering vehicles on this layout are said to have produced 100% satisfactory results.

The ULTrA PRT — although advanced in concept — is built from off-the-shelf technology, which is intended to reduce costs and enhance reliability. The electrically driven vehicle carries up to four passengers. It uses magnets and sensors in the ground for guidance and therefore needs no driver. The passengers simply select a destination and the vehicle does the rest. (In the Heathrow implementation, that means Terminal 5 or the Car Park.) In case of an obstruction, a detection system stops the vehicle and automatically alerts human personnel.

In terms of performance, you get a top speed of 25 mph (40 kph), a payload of 1,100 lbs (500 kg), and a turning circle of only 16 ft (5 m). It can handle grades of up to 20 percent, but operating routes are limited to a maximum of 10 percent “to ensure passenger comfort.”

Although the vehicles are currently driven by batteries, ATF is evaluating a range of other technologies, including solar collectors and fuel cells for future designs. At present, the system is said to be about 70 percent more energy efficient than the average automobile.

COMPUTERS AND NETWORKING

NEW ALL-IN-ONE PC

If you have always admired the iMac's all-in-one design but are firmly rooted in Windows Land, you finally have an

■ The essentially wireless Gateway One PC.

PHOTO COURTESY OF GATEWAY, INC.



option. Gateway (www.gateway.com) has just introduced the Gateway One, a sleek little desktop that does the iMac one better by giving you a wireless mouse and keyboard, essentially eliminating all cables except the power cord. And if you get it with the optional TV tuner, the machine can combine Internet browsing, gaming, music, and broadcast material in one unit.

If you get one at Best Buy, you have two choices. For \$1,300, it comes with an Intel Core 2 Duo T5250 processor, an Intel Graphics Media Accelerator X3100, a 320 GB drive, and a 1.3 Mpixel webcam. Or for \$1,800, you can upgrade to a T7250 processor, ATI Mobility Radeon™ HD 2600 XT graphics, a 400 GB drive, and a 1.3 Mpixel webcam. If you buy direct from the manufacturer, you can straddle the two and get one with the T5250 processor, ATI graphics, 400 GB drive, and the webcam for \$1,500.

Early reviews (notably by *Computer Shopper* and *CNET*) praised the machine's style and features but noted that its performance is pretty much standard for a midrange PC and registered disappointment with the “smallish” 1440 x 900 19-inch monitor. Parenthetically, as of this writing, the Taiwanese computer company Acer had extended an offer to buy all outstanding shares of Gateway at \$1.90 per share, so it may be an Acer subsidiary by the time you read this.

OPEN OFFICE V. 2.3 RELEASED

In case you aren't familiar with it, OpenOffice is a free software suite (yes, free) that is comparable with (and in many ways superior to) the Microsoft Office suite. Based on Sun Microsystems' Star Office package, it is an open-source project of OpenOffice.org (OOo) that runs on all major platforms and is compatible with other office suites.

The latest news is the release of v. 2.3, a “major release” that should be downloaded by all users because it incorporates an array of new features, fixes some newly discovered security problems, and allows full use of the growing library of extensions. Current and prospective users can download the new release from the OOo website, regardless of whether you are running Windows, Linux, Solaris, Mac OS X (X11 windowing environment required), Linux PPC, or FreeBSD.

It is noteworthy that IBM recently agreed to officially join the organization and contribute code it generated for Lotus Notes. This may expand the horizons of a group that is still largely dominated by Sun employees.

CIRCUITS AND DEVICES

THERMALLY STABLE DARLINGTONS



■ Allegro's STD01/2 series Darlington transistors offer enhanced thermal stability.

The Darlington transistor is not exactly a new technology, having been invented by Bell Labs' Sidney Darlington in 1953. He patented the idea of putting two or three transistors on a single chip which, in retrospect, seems like something of a mistake; had the patent covered any arbitrary number of transistors, it might have included all modern integrated circuits.

In any event, the venerable devices are still widely used, and an improved version was recently released by Allegro (www.allegromicro.com). Offered in a TO-3P pack-

INDUSTRY AND THE PROFESSION

FUSE BURNS OUT

In June of 1999, the Far Ultraviolet Spectroscopic Explorer (FUSE) was launched from Cape Canaveral atop a Delta-II rocket. It was a Johns Hopkins-managed NASA mission that complemented the Hubble Space Telescope by making observations in the short UV range below Hubble's capabilities. In its illustrious career, its original three-year mission was extended by NASA three times and made discoveries about everything from planets and near-by stars to galaxies and quasars billions of light-years away.

Alas, the satellite's control room went dark on October 18, leaving the 18-ft tall, 3,000-lb satellite to orbit the Earth incommunicado, awaiting its fiery demise when it enters the atmosphere in 30 years or so. Astronomers from around the world have published more than 1,200 papers based on data from the satellite, which generated spectrographs rather than photographs of distant objects. By analyzing FUSE data, astronomers were able to measure temperatures, densities, and chemical compositions of such objects, helping to place them in context in the history of the universe. For a more complete retrospective, visit fuse.pha.jhu.edu.

TECHNOLOGY TV LAUNCHED

■ The FUSE vehicle, launched in 1999, has reached journey's end.

In September, the Institute of Electrical and Electronic Engineers (IEEE, www.ieee.org) officially launched IEEE.tv, an Internet-based network that features programming on technology and engineering. The shows, which are produced by IEEE members, feature "a variety of programming options including hot topics in technology, conference highlights, and interviews with industry experts." A limited beta site appeared about a year ago, but the new version includes Flash video, a list of most viewed and recently added videos, and various options for RSS feeds. As usual, some of the juicy programs are available to members only, but there are quite a few free, public access vids, as well. You can check it out, appropriately enough, at www.ieee.tv.

PHOTO COURTESY OF JHU FUSE PROJECT.



age, the devices are designed for use in home, auto, and professional audio amplifiers. They feature a built-in thermal compensation diode on the same die, which eliminates any delay for thermal compensation operation, as well as any delay between thermal

sensing and response. The STD01 devices handle up to 100W, and the STD02s can go to 130W. Both are available in PNP and NPN versions, and they offer an operating range of -55 to 150°C.

IR THERMOMETER WITH IMPROVED SIGHTING

■ Omega's newest IR thermometer features circle/dot laser sighting.

PHOTO COURTESY OF OMEGA ENGINEERING, INC.



If you need to make quick noncontact temperature measurements, the model OSXL450 non-contact IR thermometer from Omega Engineering (www.omega.com) may be of interest. It uses a patented circle/dot point-and-shoot laser sighting system and offers a 6:1 field of view. The instrument measures temperatures from -20 to +320°C (-4 to +608°F) in less than a second. It also features a backlit display for night use and an auto shutoff.

The OSXL450 is CE compliant and is designed for a wide range of applications including manufacturing, automotive, and mining industries. The \$59 price tag even includes batteries and a wrist strap. Such a deal. **NV**

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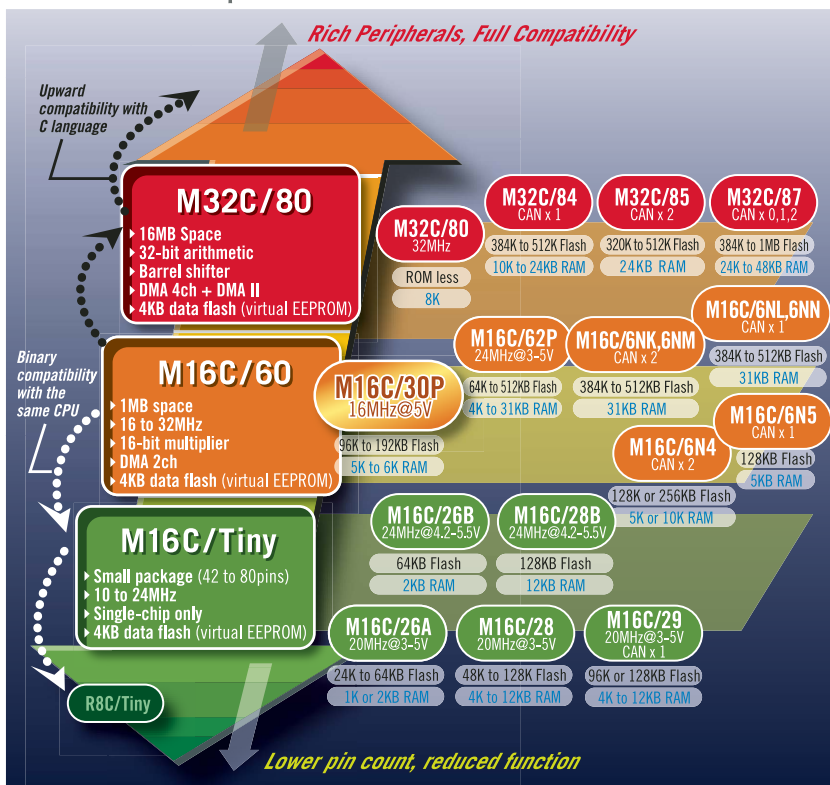
Enables connectivity with CAN, LIN, PLC, ZigBee and DMAC

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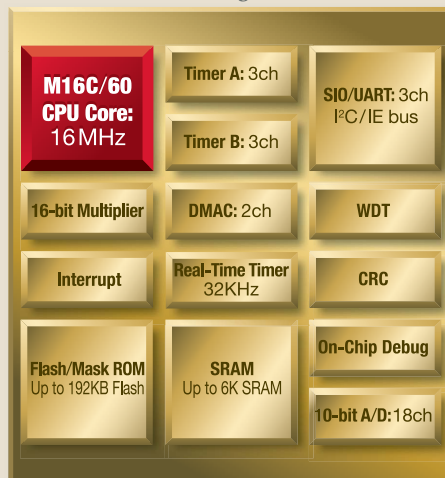
M16C Product Lineup



HOT Products	M16C/30P Group
	3 cents per pin*

* M30302F0CPGP#U5C: 100 pin, LQFP, 128K Flash / 5K RAM

M16C/30P Block Diagram



Top Reasons to select M16C MCU

- **Broad Platform & Compatibility**
 - Wide selection: 24KB to 1MB Flash, 42 to 144 pin
 - Up/downgrade in same package, same board design
 - Saves costs and protects code investment
- **Powerful and Easy**
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 - Optimized instructions for 1cycle operations
 - High-speed hardware multiplier
 - Common Tool Chain across the platform
 - Proven middleware: ZigBee, CAN, motor control
- **Versatile & Efficient**
 - Specialized peripherals: CAN, PLC, motor control
 - Efficient mapping for practical application
 - Flexible DMAC for efficient connectivity
 - Multiple clock sources and power saving modes
- **Quiet EMI/EMS**
 - Built-in noise cancellation, fewer components
- **Reliable and Secured**
 - Trusted flash and protection registers
 - Fail-safe features: oscillator-stop, non-stop WDT

Source: Gartner (March 2007) "2006 Worldwide Microcontroller Vendor Revenue" GJ07168



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■ BY LOUIS E. FRENZEL W5LEF

HOW FAR CAN YOU GO? Estimating Link Range in Wireless Applications

WITH THE NUMBER OF WIRELESS STANDARDS, products, and applications increasing almost hourly, it is a rare day in which any of us will go without some wireless usage. It will most likely be the use of a cordless telephone or cell phone, but it could also involve accessing email or the Internet via a Wi-Fi hot spot with a laptop, the use of a garage door opener, or remote keyless entry (RKE) fob for our car. Or maybe you are using a Bluetooth connection on a cell phone or a PC peripheral like a wireless mouse or maybe even a wireless temperature sensor. Whatever ...

In any case, you all know that a radio signal only carries so far. All those products I just mentioned have upper limits on the distance over which they function reliably. Those products rarely work well at the limit of their range. It is all so variable that it gives us all fits in determining what will work when and where. This makes range or distance covered the key issue in most wireless apps. Take a look at Table 1 that shows the generally accepted maximum ranges for some of the most common wireless standards.

As it turns out, there is a way you can estimate the upper limit on the

range you can get with any given wireless product. Here is an overview of how you can calculate the maximum possible range on any wireless product which you can then use to figure out a reliable maximum operating distance. And you do not have to be a rocket scientist to do it.

FIRST, THE THEORY

Remember that radio waves — which you will also hear called electromagnetic waves — are made up of two parts: a magnetic field and an electric field at right angles to one another.

British mathematician James Clerk Maxwell actually predicted such fields back in the mid-19th century and developed the math that describes them before German physicist Heinrich Hertz demonstrated them a few years later. (We know that math as Maxwell's equations.)

The equations very accurately describe how such waves will function and behave. Maxwell's equations tell us that radio waves are self-supporting in that the magnet-

ic wave regenerates the electric wave and vice versa as the signals travel from transmitter to receiver. Maxwell's equations are the basis for figuring out how radio signals are propagated.

Maxwell's math uses partial differential equations, not something most of us use on a regular basis or even know at all, for that matter. So, don't worry about having to know advanced calculus to read the rest of this article. What I will give you here is pretty simple multiplication and division on a scientific calculator.

The equation that we use most often to calculate wireless range is known as the Friis equation. It is given in all its glory below:

$$Pr = (PtGr\lambda^2) / (16\pi^2d^2)$$

Here is what each of the variables represent:

Pr = Received power
Pt = Transmitted power
Gt = Gain of the transmitting antenna
Gr = Gain of the receiving antenna
 λ = Wavelength of the signal in meters

Wireless Technology	Maximum Range
Bluetooth	10 meters
Wi-Fi 802.11 a/b/g	100 meters
Ultra Wideband (UWB)	<10 meters
ISM band RKE	<30 meters
Common cell phone to base station	2-3 miles

■ TABLE 1. Maximum ranges of popular wireless standards. Open space with simple antennas assumed.

where $\lambda = 300/f_{\text{MHz}}$
 $\pi = \text{Pi or } 3.14159$
 $d = \text{Distance or range in meters}$

If you want to know the range, you can rearrange the equation:

$$d^2 = (\text{PtGtGr}\lambda^2) / (16\pi^2\text{Pr})$$

$$d = \sqrt{(\text{PtGtGr}\lambda^2) / (16\pi^2\text{Pr})}$$

Don't let this seemingly complex equation bother you. It is just a bunch of values that you multiply together and divide by. You do have to square a couple values and use pi and maybe take a square root, but that is easy if you have a basic scientific calculator. The harder part is finding out what the various individual values are to work with.

The first thing to note is that in the RF and wireless world, we work with the power of a signal instead of voltage. As you can see, the received power is directly proportional to the transmit power.

Next, consider the antenna gain G. This is the numerical power gain, NOT expressed in decibels (dB). All practical antennas have some gain because they exhibit directional characteristics. The ideal theoretical antenna is called an isotropic radiator and is an RF point source that radiates equally well in all directions creating a spherical antenna radiation pattern. Real antennas don't have that kind of radiation pattern as they tend to radiate better in some directions rather than others.

For most applications, using a plain old half wave dipole or quarter wave ground plane antenna, the power gain is 1.64. Other antennas (like a Yagi or collinear) have much greater gains. And remember that the gain is not really an actual multiplication in power level. Instead, the gain comes strictly by way of focusing or concentrating the available power into a narrower beam. This gives you what is called the effective radiated power (ERP). In wireless applications, such gain is just as effective as increasing the actual transmit power.

Another important thing to note is that the wavelength of the signal is of major importance. The longer the wavelength, the greater the range. Recall that wavelength is related to frequency by the simple expression given earlier: $\lambda =$

$300/f_{\text{MHz}}$. What this tells you is that signals at the lower frequencies travel farther than at the higher frequency signals. Over the years, we have pushed upward into the UHF and microwave spectrum to get more space for new radio signals and services. There is lots of room in the microwave bands, but as the frequency gets higher, the range becomes much less by the square of the wavelength. That is a major factor.

A good example is that cell phone sites or base stations operating in the 800 to 900 MHz range have a much greater area of coverage than those operating in the 1800 to 1900 MHz range. You have to use more cell sites at the higher frequencies to get the same coverage. It is much more expensive. Of course, you can overcome that limitation by increasing transmit power or increasing either or both antenna gains and heights. But there are regulations and other limits that may thwart those plans.

One final thing. This formula is only good for ground and direct or space wave propagation. Ground waves are radio signals that hug the earth and are the main wave used in low frequency operation (<3 MHz). Think AM radio. Space waves are the direct line-of-sight (LOS) waves characteristic of VHF, UHF, and microwaves. Think TV or two-way radio. The formula does not work accurately for sky waves that are refracted from the ionosphere for long distances. These waves are the so-called short waves in the 3 to 30 MHz range.

PATH LOSS

As you can see from the basic formula, the signal loss is inversely proportional to the square of the distance. Doubling the distance quadruples the loss. And there is a way to find what that path loss is in dB.

$$\text{dB loss} = 37 \text{ dB} + 20 \log(f) + 20 \log(d)$$

In this formula, f is the frequency in MHz and d is the range or distance in miles. Just use your scientific calculator to find the logarithms. And don't forget, we are dealing with power loss here.

The formula assumes isotropic antennas so the result is usually the worst case. An example calculation

PATH LOSS CALCULATION

What is the path loss for a 900 MHz signal over a range of four miles?

$$\text{dB loss} = 37 \text{ dB} + 20 \log(f) + 20 \log(d)$$

$$\text{dB loss} = 37 \text{ dB} + 20 \log(900) + 20 \log(4)$$

$$\text{dB loss} = 37 + 59 + 12 = 108$$

This would be expressed as -108 dB. Call it Ploss.

is given in the Path Loss Calculation sidebar.

THE IMPORTANCE OF RECEIVER SENSITIVITY

One thing not shown in any of the formulas is the receiver sensitivity. Sensitivity is a measure of how much gain the receiver has ... that is how much it amplifies small signals. It is a common specification in most wireless transceiver chips, boards, and modules. And wow, is it important. Like the transmit power, it is the key to establishing a solid wireless link between two points. The combination of transmit power, path loss, and receiver sensitivity are related as this formula shows.

$$\text{Pr} = \text{Pt} - \text{Ploss}$$

In this formula, Pr is the received power and Pt is the transmit power both given in dBm, or decibels referenced to one milliwatt. You calculate Pt with the expression:

$$\text{Pt (dBm)} = 10 \log(\text{Pt}/0.001)$$

For example, assume a transmit power of 600 milliwatts (0.6 watt). In dBm, this is:

$$\text{Pt (dBm)} = 10 \log(600) = 27.8 \text{ dBm}$$

Now you can figure the received power. Assume the path loss of 108 dB as calculated earlier. The received power then is:

$$\text{Pr} = 27.8 - 108 = -80.2 \text{ dBm}$$

What this tells you is with the

RANGE CALCULATION EXAMPLE

What is the maximum theoretical range of a wireless system that transmits 600 mW on 900 MHz with isotropic receive and transmit antennas?

First, calculate the wavelength in meters:

$$\lambda = 300/f_{\text{MHz}} = 300/900 = 0.333 \text{ meter}$$

$$d = \sqrt{(PtGtGr\lambda^2) / (16\pi^2 Pr)}$$

$$d = \sqrt{[(0.6)(1)(1)(0.333)^2 / 16(3.14159)^2(9.55 \times 10^{-12})]}$$

Note that I used antenna gains of one since the path loss calculation assumed that isotropic antennas are used.

$$d = 6640 \text{ meters}$$

Since there are 1609 meters per mile, the range is:

$$d = 6640/1609 = 4.126 \text{ miles}$$

That is pretty close to the four mile range assumed in the original path loss calculation above, given all the rounding of numbers during the calculations. Using practical antennas — even simple ground planes or dipoles — the actual possible range would be even greater because of the gain.

You can see that the calculations are pretty reliable.

given transmit power and the calculated path loss, you will need a receiver sensitivity of at least -80.2 dBm to get a reliable connection. Luckily, most receivers have a sensitivity much better than that.

At this point, you could calculate the minimum receive power using the sensitivity value in dBm. It involves taking the antilog (\log^{-1}). The formula is:

$$Pr = 0.001 \log^{-1} (\text{dBm}/10)$$

Use the antilog buttons on your calculator to get the value.

$$Pr = 0.001 \log^{-1} (80.2/10) = 9.55 \times 10^{-12} \text{ or } 9.55 \text{ picowatt (pW)}$$

ANTENNA HEIGHT EXAMPLE

Assume a transmitter antenna height of 70 feet and a receive antenna height of six feet. The maximum range is:

$$d = \sqrt{(2ht)} + \sqrt{(2hr)}$$

$$d = \sqrt{(2)(70)} + \sqrt{(2)(6)}$$

$$d = \sqrt{(140)} + \sqrt{(12)} = 15.3 \text{ miles}$$

Pretty small signal, which is not unusual.

LINE OF SIGHT DISTANCE

Most VHF, UHF, and microwave signals are line-of-sight as indicated earlier. The actual LOS range depends on antenna height. If you try to go too far without the necessary antenna height, you will not establish a link. The formula below shows the relationship between range and antenna heights.

$$d = \sqrt{(2ht)} + \sqrt{(2hr)}$$

In this case, d is the range as usual in miles, ht is the transmit antenna height in feet, and hr is the receive antenna height in feet. This is the maximum possible range with those heights.

NOW A REALITY CHECK

All the above is theoretical, but it does work out pretty close to that in the real world, assuming you are operating in an open, free space environment. Yet there are some other factors that come into play you have to be aware of.

In wireless, nothing is perfect. You always have stuff beyond your control that will keep the signal from getting from point A to point B. Here are the main culprits.

- **Noise** — Noise is that random variation caused by the atmosphere and man-made sources that add to the signal and reducing its intelligibility at the receiver. The goal of course is a high signal to noise power ratio (SNR). If noise is too high it can obliterate the signal meaning no reception.

- **Interference** — Interference is made up of signals from other sources on or near the same operational frequency. It could come from other

wireless devices nearby or it could even be spurious radiations like harmonics from some other source. Interference keeps you from making sense of the received information, strong signal or not.

- **Multipath** — Multipath is the phenomenon of the transmitted signal being reflected from objects in the path to the receiver. For example, signals will bounce off buildings, cars, trees, even people. As a result, multiple signals reach the receiver along with the directly transmitted signal. These multipath signals are delayed a bit so add to and subtract from the main signal producing fading and signal cancellation.

- **Obstacles** — Radio signals travel freely in open space. But when you use wireless devices indoors (as most of us do these days), obstacles like walls, ceilings, and floors — not to mention furniture or other devices like machines — really mess up the signal. These obstacles won't usually stop the signal completely, they will greatly attenuate the signal. The attenuation is particularly high when multiple walls have to be penetrated. The type of wall makes a difference, too. That is why it is so difficult to reliably predict any kind of range indoors. These indoor obstacles also add to the multipath effects, also greatly limiting range.

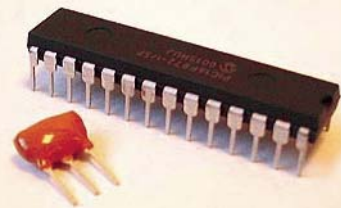
The main solution to these problems is to use as much transmit power as the FCC regulations allow and the application can afford. Also, be sure your receiver has the best sensitivity possible. Some really good cell phone and other wireless chips have sensitivities up to -140 dBm.

The other great solution is to use a gain or directional antenna such as a Yagi, collinear, or patch array. This not only gives the signal a real power boost, it also narrows the signal beam making multipath problems less of an issue.

If you are putting together a wireless product or system, use these calculations as they will indeed get you into the ball park. Then, just be sure to include a little extra margin in transmit power, receiver sensitivity, and antenna gain and it will work very reliably. **NV**

PICAXE PRIMER

SHARPENING YOUR TOOLS OF CREATIVITY



■ BY RON HACKETT

WELCOME TO THE POWER OF PICAXE

WELCOME TO THE FIRST INSTALLMENT OF PICAXE Primer, a column dedicated to “spreading the word” about the ease, power, and versatility of programming and project-building with the unique microcontrollers. Every other month, we will focus on one or two aspects of using these chips as well as responding to issues and questions raised by readers along the way.

First let me say that PICAXE is a licensed, registered trademark used exclusively by Revolution Education, Ltd. (www.picaxe.co.uk). The first PICAXE chip was developed by RevEd in 2002 in the United Kingdom, with funding provided by the oil and gas industries. Known as the PICAXE-08, this chip was intended primarily for use in UK public schools. As a result, it is extremely easy to program and surprisingly inexpensive.

In 2004, RevEd announced the PICAXE-08M, which added many new features to the original 08, and quickly became the entry-level chip of choice. The 08M is currently available

for less than \$4 (see Sources) and is a great place to start if you are new to PICAXE programming.

During the past six years, this line of microcontrollers has grown in size and complexity, but each new PICAXE chip retains the original characteristics of economy and ease of programming. There are currently 11 microcontrollers in the product line, ranging in size from eight pins to 40 pins.

Figure 1 presents the major features of the most recent microcontrollers in each of the five size categories (8, 14, 18, 28, and 40 pins). In future PICAXE Primer columns, we will explore various features of each of these chips, but

for the moment we'll get started with the 08M.

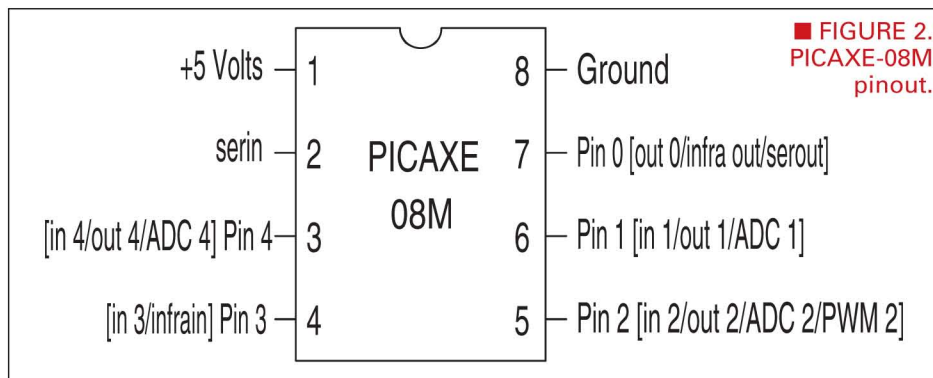
As you can see in Figure 1, this is the least powerful chip in the PICAXE line-up. However, it's still an amazing little chip, and has more than enough power for a variety of interesting and useful projects.

GETTING STARTED

If you are just getting started with PICAXE chips, the first step is to visit their website (www.rev-ed.co.uk/picaxe). While you are there, be sure to download all three sections of the PICAXE manual (“Getting Started,” “Basic Commands,” and “Interfacing

■ **FIGURE 1.** Features summary of selected PICAXE processors.

	PICAXE-08M	PICAXE-14M	PICAXE-18X	PICAXE-28XI	PICAXE-40X1
Pins	8	14	18	28	40
I/O Pins	5	11	14	21	32
Input Pins	1 - 4	2 - 5	5	4 - 12	8 - 20
Output Pins	4 - 1	9 - 6	9	17 - 9	17 - 9
10-Bit ADC Pins	3	2 - 4	3	0 - 4	7 - 3
PWM Pins	1	1	1	2	2
BASIC Program Memory	~ 80 lines	~ 80 lines	~ 600 lines	~ 1000 lines	~ 1000 lines
General Purpose Vars.	14 bytes	14 bytes	14 bytes	28 bytes	28 bytes
Storage Vars. (peek/poke)	48 bytes	48 bytes	96 bytes	96 bytes	96 bytes
Scratchpad Vars. (get/put)	-	-	-	128 bytes	128 bytes
Special Word Vars.	-	-	-	8 bytes	8 bytes
Data Memory (EEPROM)	256 - Program	256 - Program	256 bytes	256 bytes	256 bytes
Maximum Speed	8 MHz	8 MHz	8 MHz	20 MHz	20 MHz



Circuits"); there's a wealth of information to get you going.

Secondly, download the latest version of the free PICAXE Programming Editor, available from the "Software" tab at the top of their home page. For convenient reference, all documentation is also available under the "Help" menu of the Programming Editor.

Finally, while you are at the PICAXE website, check out the discussion forum (www.rev-ed.co.uk/picaxe/forum). It's the meeting place for more than 45,000 PICAXE enthusiasts, and a resource that is well worth joining. I have found that a quick search of the forum archives almost

always provides helpful answers to any question I have. In the rare instances I can't find what I need, posting my question to the forum always yields very helpful information from several members.

Figure 2 presents the pin-out of the 08M, which has five general-purpose input/output pins. I/O pin 0 (external pin 7) is output only, I/O pin 3 (external pin 4) is input only, and the other three I/O pins (1, 2, and 4; external pins 6, 5, and 3, respectively) can be individually programmed as inputs or outputs.

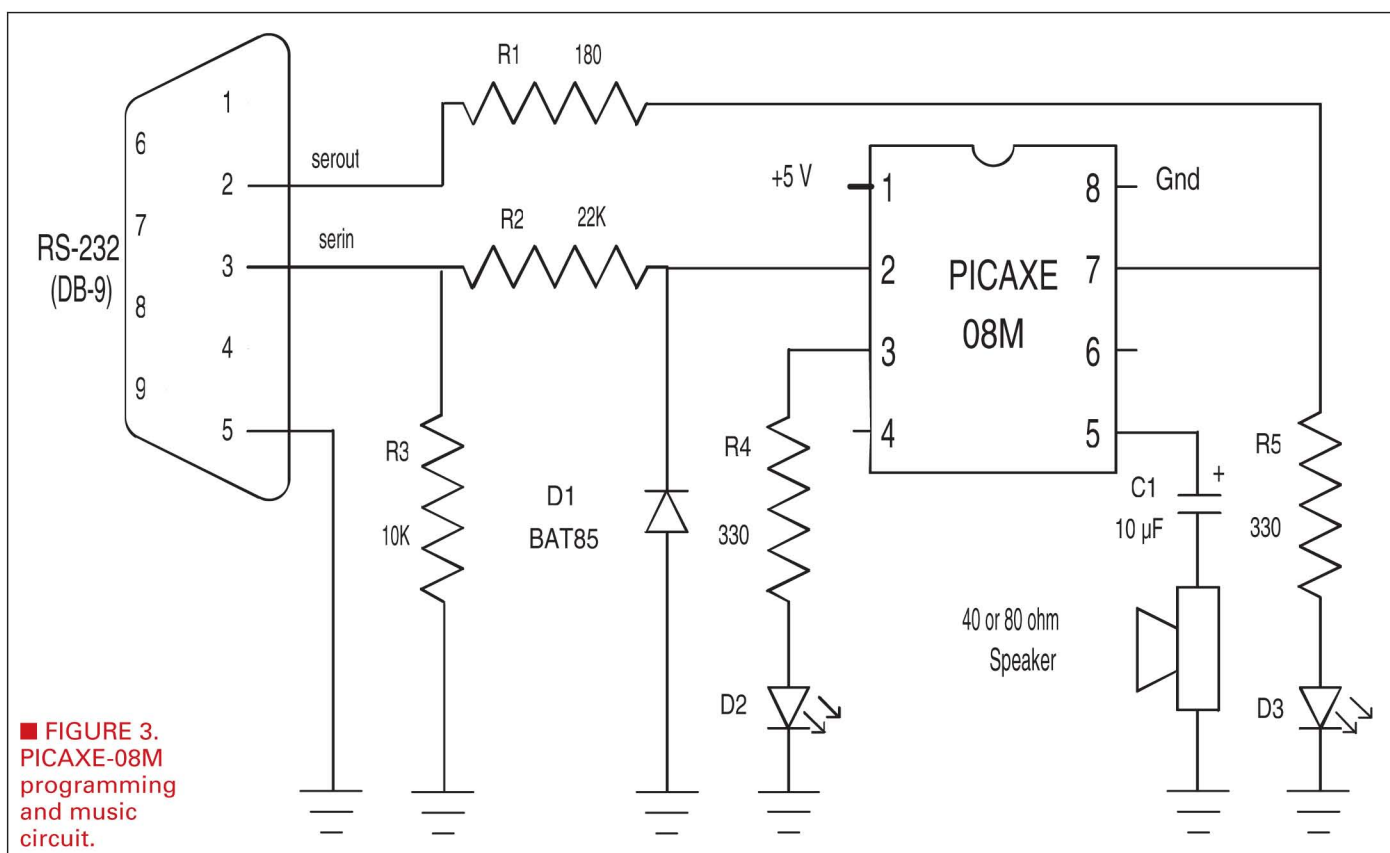
As shown in Figure 2, all of the I/O pins have multiple functions,

which are thoroughly discussed in the reference manual. As you can also see in Figure 2, the 08M has no external pins for a dedicated crystal or ceramic resonator; instead, it has a built-in 4 MHz RC oscillator which is switchable to 8 MHz under programmatic control. This is a great feature, since it frees up two of the 08M's pins for general-purpose I/O.

On the down side, however, the internal oscillator is not as accurate as an external crystal or ceramic resonator, but it is accurate enough for the types of tasks called for in a wide variety of projects. If your project requires greater timing accuracy, there is a Basic command (calibfreq) that allows you to fine-tune the 08M's operating frequency. Of course, you will need a frequency counter or oscilloscope to determine when you have it right.

PROGRAMMING A PICAXE

All PICAXE chips are programmed using the same simple three-wire



interface to your PC's serial port. To implement that interface, you can purchase the "official" Revolution Education PICAXE programming cable (in a serial or USB form), or you can simply solder three short jumper wires to a DB-9 serial connector and plug the other end of each wire into your breadboard.

Over the years, I have experimented with several variations on this theme, and have settled on an approach that avoids soldering altogether. I now make all my PICAXE programming cables from 9 or 10 wire ribbon cable and connectors. All three programming cable options are discussed in detail on my website (www.jrhackett.net/cable.htm). If you want to get started quickly, you can just refer to Figure 3 to construct a simple cable. It also includes the complete circuitry for our music project, which we will discuss shortly.

Figure 3 also includes three resistors and a diode in the programming interface circuitry. Actually, only resistors R2 and R3 are required — on the serout line, resistor R1 is optional; downloading your program will work properly without it. However, R1 does provide short-circuit and static protection on the serout line and it's probably a good idea to include it, especially if you are like me and sometimes accidentally plug wires into the wrong hole on the breadboard!

As indicated in Figure 3, RevEd specifies 180 Ω for this resistor. However, I have found that a 220 Ω resistor works just as well, and is much more readily available. The BAT85 diode is also optional — it provides a more accurate voltage reference for the serial transfer.

If downloads from your PC work reliably without the diode, you don't need it; if downloading is a little flakey at times, try including the BAT85 diode — just be sure to install it "backwards," i.e., with its anode (rather than its cathode) connected to ground.

As you may have noticed back in Figure 2, the serial output pin can also function as a general-purpose

output. If your output is as simple as an LED, you can leave it and the programming cable connected at the same time. If you do, the LED will flicker during program download, which can be a reassuring indication that downloading is proceeding properly. However, if you are using output 0 for something more involved (e.g., motor-control), it's best to disconnect your output during program download. To avoid the hassle, it's easier to use output 0 for an LED whenever possible.

MUSIC, MAESTRO!

For our first PICAXE programming project, we will take a look at the 08M's music-making capabilities, which are surprisingly sophisticated. Of course, music isn't the only talent available — in addition to the usual BASIC commands (branch, count, do...loop, for...next, gosub, goto, if...then...else, select case, etc.), the 08M has many specialized commands to accomplish a variety of useful tasks in a simple manner.

In addition to the music-related commands there are Basic commands for analog-to-digital conversion, infrared input and output, interrupt processing, PC keyboard input, pulse-length measurement and production, pulse-width modulation (PWM) for motor control, serial I/O, servo-motor control, SPI input and output, table lookup and lookdown, and temperature measurement, to name just a few!

The details for all of the 08M Basic commands are presented in Part 2 of the PICAXE manual. If you are especially interested in any of these areas, send me an email — it will help me to select future topics of the PICAXE Primer from the myriad of possibilities.

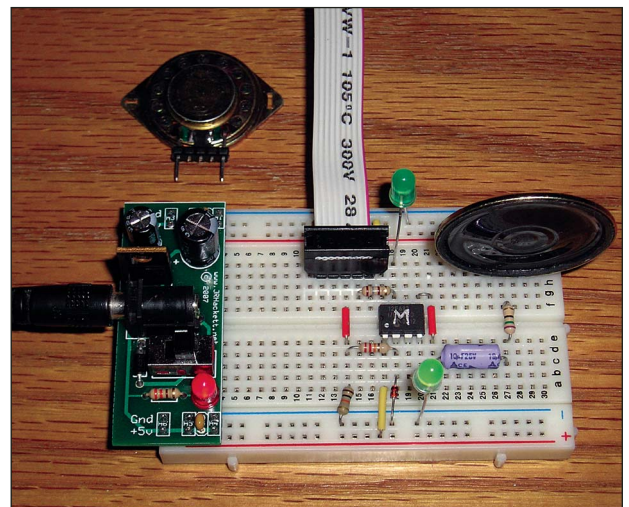
Figure 3 (presented earlier) includes the

complete schematic for our explorations of music making with the 08M. I adapted the circuit from a similar one presented in the documentation for the "tune" command discussed in the manual. As you can see, a 40 Ω or 80 Ω speaker is specified; however, small 8 Ω and 16 Ω speakers are far more common.

The PICAXE documentation indicates that an 8 Ω speaker may also be used if a 33 Ω resistor is connected in series to make the total resistance equal to 41 Ω . The closest I could come to that was a 75 Ω resistor in series with a 16 Ω speaker. This combination worked fine, but feel free to experiment with the parts you have on hand — just be sure to make the total resistance (speaker and series resistor) greater than 40 Ω .

A photo of the completed breadboard circuit is shown in Figure 4. The extra speaker in the upper-left corner shows how I soldered a pin header to the speaker contacts. If you have read any of my earlier articles, you may have already guessed that I'm not a fan of dangling wires or parts in a breadboard circuit (avoiding them helps me sleep at night!), but you certainly could just solder two wires to the speaker contacts and plug the other end of each wire into the breadboard.

The 5V power supply board in the photo is available on my website, but you can use any regulated 5V supply, or even three AA batteries — a nominal 4.5V supply would be fine for this simple circuit. (Never try to



■ **FIGURE 4.**
The completed breadboard circuitry.



Value	Tune	LED
0	"Happy Birthday"	No outputs flash on and off
1	"Jingle Bells"	Output 0 flashes on and off
2	"Silent Night"	Output 4 flashes on and off
3	"Rudolph"	Outputs 0&4 flash alternately

power a PICAXE circuit with four 1.5 volt batteries — six volts will more than likely damage or destroy your the chip!)

Finally, the programming cable in the photo is the one I mentioned earlier; but three wires soldered to a DB-9 connector would work just as well.

All PICAXE chips are actually Microchip PICmicro devices with RevEd's proprietary Basic interpreter stored in an area of permanent memory; for example, the PICAXE-08M is actually a PICmicro 12F683. As a result, all PICAXE I/O pins are capable of sourcing or sinking a maximum of 25 mA. Therefore, LEDs can be directly driven as long as an appropriate current-limiting resistor is included in the output circuit.

If you look closely at the photo in Figure 4, you won't see the current-limiting resistors for each of the LEDs because they are built into the LEDs I am using, which makes breadboarding a little simpler. If you are interested in these LEDs, see the Sources sidebar.

MUSICAL TRAINING WHEELS

For our first music program, we are going to take the "short-cut" approach. Every 08M has four complete melodies pre-installed in a special section of its memory: "Happy Birthday," "Jingle Bells," "Silent Night," and "Rudolph the Red-Nosed Reindeer." Since we are rapidly approaching the holiday season, we'll use "Rudolph" for our first mini-concert.

All that's necessary to play "Rudolph" using the 08M is the inclusion of a simple "play" command, with the following syntax: "play tune, LED." The "tune" parameter specifies which tune to play and the "LED" parameter provides the option of flashing one or two LEDs in time with the music.

You may have noticed that we didn't specify which I/O pin to use; that's because the play command only functions on output 2 (pin 5) of the 08M. On other PICAXE chips that support the play

■ FIGURE 5. Parameter values for "play" command.

command, the output pin must also be specified. Again, see the PICAXE Manual for details.

The program necessary to play "Rudolph" couldn't be simpler — in fact, it only requires one Basic command (play 3, 3) to generate the music. As indicated in Figure 5, the first "3" selects "Rudolph" as the tune to play, and the second "3" specifies that we want the LEDs on outputs 0 and 4 to alternately flash in time with the music. If you already have experience with PICAXE programming, assemble the circuit presented earlier in Figure 3, and include a "play 3, 3" command in a simple test program.

Of course, readers who are new to programming will first need to download the latest version of the free Programming Editor software from Revolution Education (www.rev-ed.co.uk/picaxe/). There isn't space here to go into detail on how to use the software, but it's very intuitive and includes ample documentation. In case you need it to get started, a complete PICAXE test program to play "Rudolph" is presented in Figure 6. Just type it into the Programming editor and download it to your 08M. If you have problems getting the program to run properly, send me an email at Ron@JRHackett.net and I will do what I can to help. When you have the program running properly, you may want to experiment with changing the parameters of the play command.

EXPANDING OUR REPERTOIRE

Of course, if we had only four songs to choose from, boredom would set in very quickly! Fortunately, the "tune" command can rescue us from the tedium by enabling us to play any tune we choose. In case you have any apprehensions about the need to be a digital Mozart, there are nearly

■ FIGURE 6. Simple Basic program to play "Rudolph."

```
'==== Rudolph.bas ===== 2007.10.10 ===== Ron Hackett =====
'
'      This program runs on a PICAXE-08M processor.
'      It repetitively plays "Rudolph the Red-Nosed Reindeer"
'      & alternately blinks LEDs on outputs 0 & 4 (pins 7 & 3)
'      in time with the music.
'

'==== Directives ====

      #com1          ; specify which com port
      #picaxe 08M    ; specify which PICAXE chip

'==== Main Program =====
main:
      play 3,3; play "Rudolph" and blink LEDs
      wait 2          ; 2 second delay between repetitions

      goto main       ; do it again, forever
                      ; or until you can't stand it any more!
```

1,000 tunes available for free downloading at the Revolution Education website. Just go to the RevEd software page, and scroll down to the "Additional Resources" section near the bottom of the page. You will find five zipped files containing the tunes.

In addition, the 08M can play any monophonic ringtone in RTTTL (ring tones text transfer language) format, the kind used on most Nokia cell phones. The Additional Resources section also contains two zipped ringtone files, as well as links to websites where you can download more free ringtones.

We don't have space to explore the tune command this time, but we will do so in the next installment of the PICAXE Primer.

LOOKING AHEAD

The PICAXE-08M packs a tremendous amount of computing power in a very small package and at a surprisingly affordable price. We have barely scratched the surface of the capabilities of this amazing little chip.

In addition to the tune command, I can think of several other areas of that are worth exploring in future installments of this column. Infrared input and output, interrupt processing, and temperature measurement are currently on the top of my list, but what gets discussed in this column is also up to you! If there is a PICAXE topic that you would like covered, email me. Your feedback will be a major factor in determining the direction of future columns.



One final note — by the time you read this column, my new PICAXE Primed blog should be up and run-


ning on the *Nuts & Volts* website. In a way, the blog will be a companion to this column. It's a place where I can mention various thoughts and possibilities that occur to me in the area of PICAXE programming and project-building and include "up-to-the-minute" news from the PICAXE world, such as preliminary details on the soon-to-be-released PICAXE-28X2 and -40X2 chips, which are bound to further increase

the power and versatility of the microcontroller line.

The PICAXE Primed blog is also designed to be interactive; readers are invited (and encouraged) to respond to my musings, and to contribute their own ideas, as well. I'm looking forward to the feedback, and I'll definitely take your comments into consideration as I decide on future content. So, check out the blog, and let me know what you think! **NV**

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SOURCES

PICAXE-08M:
www.hvwttech.com
www.JRHackett.net
www.phanderson.com
www.picaxe.co.uk

Five-volt Resistorized LED:
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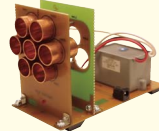


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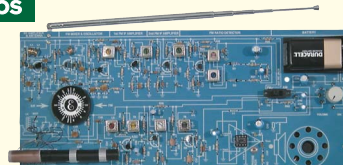


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Q&A

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✓ DC Light Dimmer
- ✓ Three to 12 Volt Converter
- ✓ Ignition Coil Test

WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:

Q&A@nutsvolts.com

FOUR PHASE AC SIGNAL

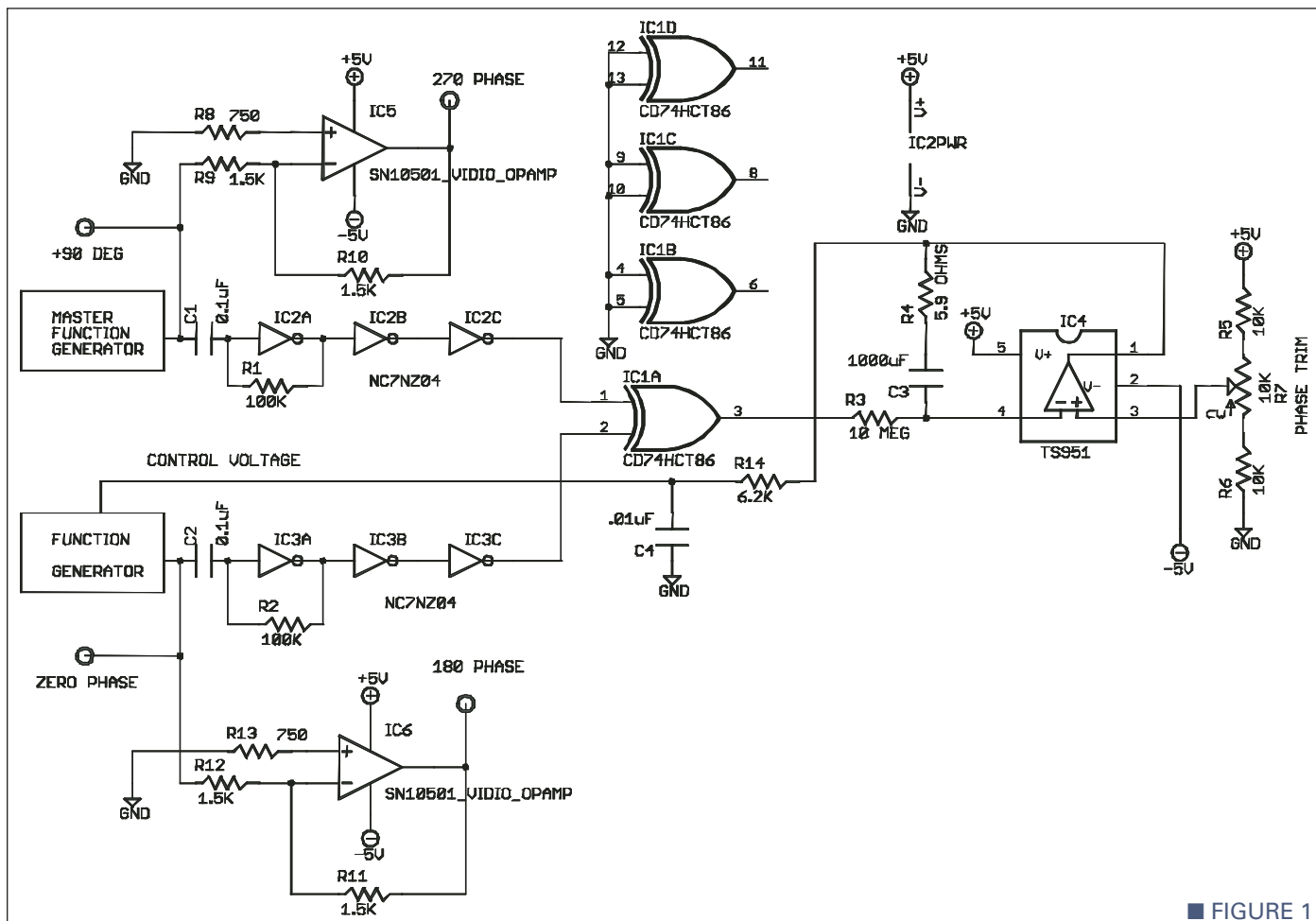
Q I have an arbitrary waveform generator at my disposal and I want to split its sine wave generated signal (1-10 MHz, 0-20 Vpp) into four outputs. The output

signals need to be similar at 0, 90, 180, and 270 degrees out of phase with each other. Eventually, I may be working with signals at higher frequencies (up to 100 MHz). Could you please suggest a circuit and component design for this project? I have seen four-phase signal generators on the market priced for over \$5,000 and

I am looking for a low-cost alternative. Thank you for your help.

— Stuart Williams

A 180 degrees is just the inversion of 0 degrees and 270 degrees is the inversion of 90 degrees, so all you



■ FIGURE 1

need is one 90 degree generator and two inverters. It is possible to design constant phase difference filters but they have limited bandwidth. It seems to me the best solution is to have two arbitrary waveform generators in a 90 degree phase lock loop. I first thought of using a divide by four Johnson counter because it has the required four phases of output, but it requires a master oscillator four times the output frequency.

The B&K Precision model 4017A covers 0.1 Hz to 10 MHz and has a voltage control input. Figure 1 is the basic idea. The XOR phase detector works over 0 to 180 degrees and will hold 90 degrees phase difference between the two inputs. In order to have zero error of phase, an integrator (type 2 PLL) is needed. This type of PLL is inherently unstable, so lead-lag compensation is necessary. I took a guesstimate of the voltage controlled oscillator sensitivity; the data sheet for the model 4017A says ± 1 volt gives 100:1 frequency change so I used 500 MHz per volt sensitivity at 10 MHz.

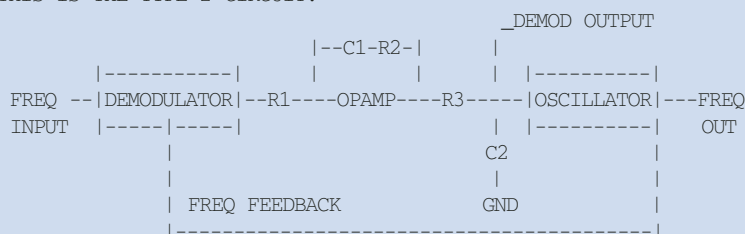
The design uses surface-mount parts and layout will be critical. I don't know that the NC7NZ04 inverter is stable with feedback; I have done it successfully with lower frequency inverters. The inverter is capable of

SUMMARY OF COMPONENT VALUES

DEMODULATOR CONSTANT	= 2.546481 VOLTS PER RADIAN
INTEGRATOR CONSTANT	= 9.423764E-05 1/SEC
OSCILLATOR CONSTANT	= 3.14159E+09 RADIAN/SEC/VOLT
FIRST CUT FREQ (LEAD)	= 25.52905 HZ
SECOND CUT FREQ. (LAG)	= 2552.905 HZ
CLOSED LOOP BANDWIDTH	= 1000 HZ
RESPONSE TIME	= .0004 SEC
PULL-IN RANGE	= 2256417 HZ
R1=	1E+07
R2=	5.875033
R3=	6234.274
C1=	1.061147E-03
C2=	1E-08
DELTAG=	0
FCT=	0

■ FIGURE 2

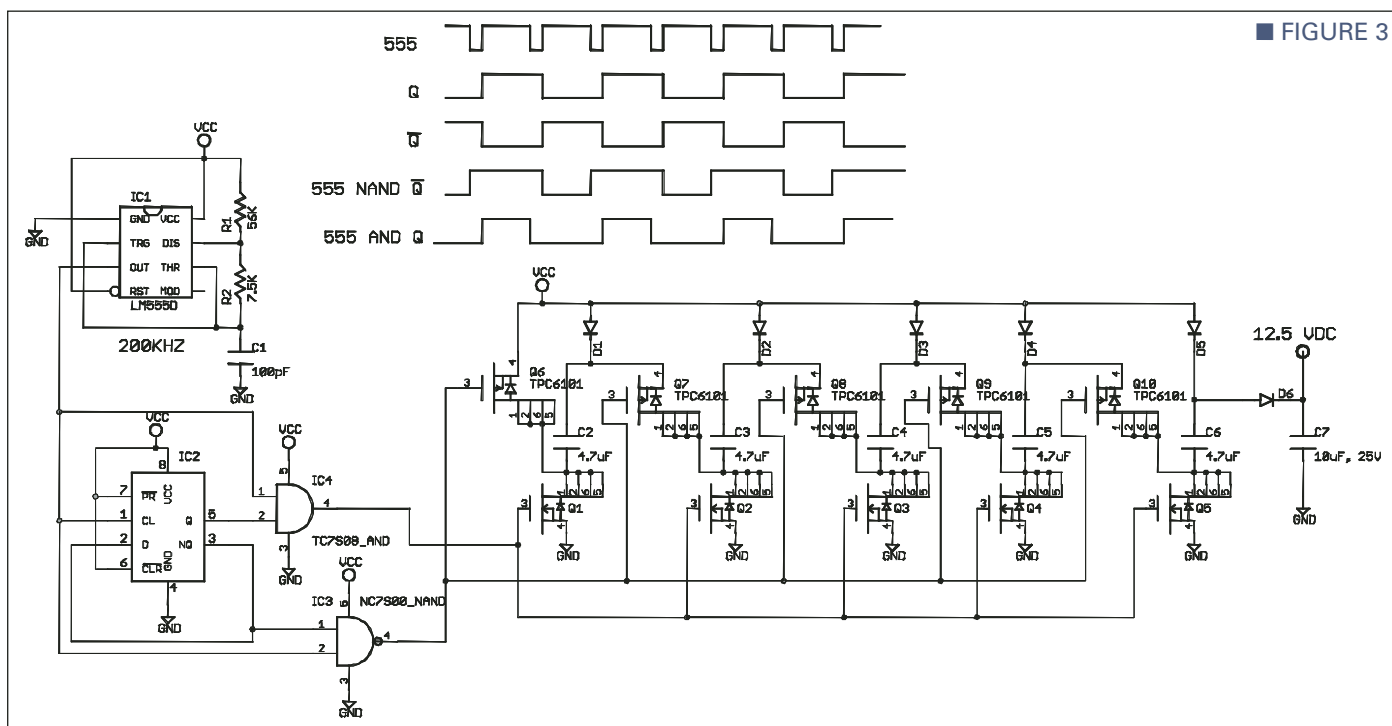
THIS IS THE TYPE 2 CIRCUIT:



oscillating at 100 MHz so any inductance in the feedback could make it oscillate. The SN10501 video op-amp has a gain bandwidth of 170 MHz so good high frequency layout will be essential.

Figure 2 lists the parameters for

the PLL. It may be necessary to change the value of R3 from 10 meg to 2 meg in order to maintain stability of the range of 10 MHz to 1 MHz; and all the values will change if the oscillator sensitivity is very different from what I estimated.



■ FIGURE 3

■ FIGURE 4

PART	DESCRIPTION	PART NUMBER	SUPPLIER
• R1	56K, 5%, 1/8W	263-56K-RC	MOUSER
• R2	7.5K, 5%, 1/8W	263-7.5K-RC	MOUSER
• C1-C4	100 pF, 5%, NPO	140-CC501N101J-RC	MOUSER
• C5, C6	4.7 μF, 10%, 10V, X7R	81-GRM426X475K10L	MOUSER
• C7	10 μF, 10%, 25V, X7R	81-GRM32DR71E106KA12	MOUSER
• D1-D6	SCHOTTKY, 1A, 50V	512-RS1A	MOUSER
• IC1	LMC555D TIMER	511-TS555ID	MOUSER
• IC2	D-FF, TINY LOGIC	512-NC7SZ74K8X	MOUSER
• IC3	NAND, TINY LOGIC	512-NC7ST00M5X	MOUSER
• IC4	AND, TINY LOGIC	512-NC7S08M5X	MOUSER
• Q1-Q5	NMOS, 20V, 3A, 2.5VGS	512-SI3442DV	MOUSER
• Q6-Q10	PMOS, 20V, 4A, 2.5VGS	TPC6101CT-ND	DIGI-KEY

The parts are all surface-mount; the transistors have four drain connections in order to improve heat dissipation. The transistor switches are running at 100 kHz and could no doubt go faster, but the logic gates are driving a lot of capacitance so a buffer/driver might be needed. If anyone builds this, please let me know how it works! The list is shown in Figure 4.

Q I am working on a project to convert 3V DC to 12V DC, using all the available parts I can find. I tried to use transistors, resistors, capacitors, and diodes but could not get it right. Is there a better diagram to connect all these together?

A The easiest solution is to use a boost IC, of course. But, if you want to use discrete components, I am up for a challenge. How about a switched capacitor solution? Charge five caps in parallel and connect them in series to

In Figure 3, Q1 charges C2 through D1; Q2 charges C3 through D2, etc. When the NMOS transistors turn off and the PMOS transistors turn on, Q6 connects C2 in series with VCC, Q7 connects C3 in series with C2, etc., and finally, D6 dumps all the charges into C7. I estimated 2.5 volts charge on each cap so the output should be about 12 volts.

I could have connected the PMOS and NMOS gates together and it would have worked, but when the PMOS was turning off and the NMOS was turning on, there would be a large shoot-thru current that would heat the transistors and waste power. What is needed is a dead time when both

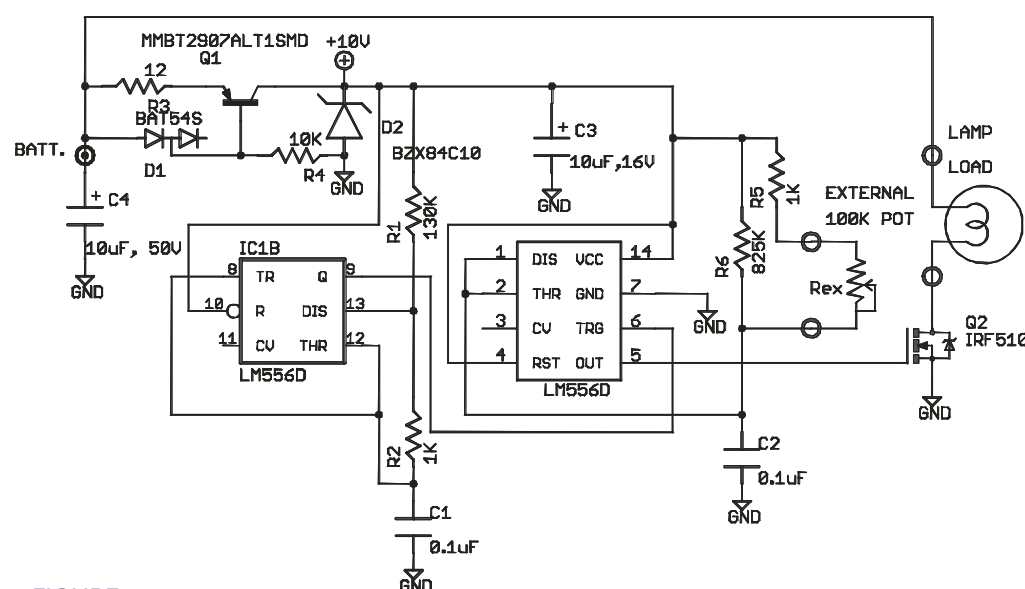
Q I have a marine application for a DC light dimmer that will operate between 11-14.8 VDC with a 20 watt or less load. The circuit should be compact to fit inside the base of a surface mounted light.

— Bill Taylor

A This seems to me a natural for a couple of 555s. The frequency only has to be high enough that you can't see the flicker, say 100 Hz. The first 555 is an astable at 100 Hz, the second is triggered by the first and has a variable one shot time, varied by Rex. If the one shot time exceeds 10 ms, the output will skip pulses and the light will dim. Maximum brightness is just short of 10 ms one shot time.

In the circuit (Figure 5), Q1 is a current source rated at 60 volts and 20 mA to protect the circuit from voltage spikes. The MOSFET switch is rated at five amps, so a 40 watt load is okay. The resistor, R6, in parallel with R5 and the external 100K pot is calculated to be 90K, which should prevent pulse skipping. The IC is a 556 which is a dual 555.

The parts are all surface-mount and will fit on a two inch square PC board.



■ FIGURE 5

IGNITION COIL TEST

Q I need a circuit to power and trigger automotive ignition coils to verify if they are dead or alive. I plan to use the circuit in Figure 4 (fly zapper) of the September '07 issue to see the spark jump a 3/8 inch gap. Is this the best approach or is there a simpler way?

— Jim Tea

A The simplest tester would be a push button switch but then you would not have control of the dwell angle. The frequency of the circuit in Figure 4 of the September issue was chosen to be above the audible range, but a four cylinder engine running at 4,000 RPM will operate the coil at a lower frequency:

$4,000 \text{ R/M divided by } 60 \text{ S/M} = 66.7 \text{ R/S}$

There are four cylinders: $66.7 \text{ R/S} * \text{strokes/R} = 266.8 \text{ strokes/S}$

But it takes two revolutions to complete the four stroke cycle; that's the reason the distributor runs at half the motor RPM.

$266.8/2 = 133.4 \text{ Hz}$ firing rate for the coil at 4,000 RPM

The distributor makes one revolution in 7.4 ms, leaving 1.85 ms per cylinder, and figuring 50% dwell angle, the on-time of the switch is .926 ms. Round that off to 1 ms. An eight cylinder engine has to divide the 7.4 ms by 8, so the on-time of the switch is 0.5 ms. That is one reason that the old Ford V8 was popular with stock car racers; the engine was built like two four cylinder engines with separate points, allowing it to run at higher RPM.

But I digress; getting back to this circuit, a 3/8 spark gap is good at sea level because the voltage required to jump an .060" gap under compression is much greater than at

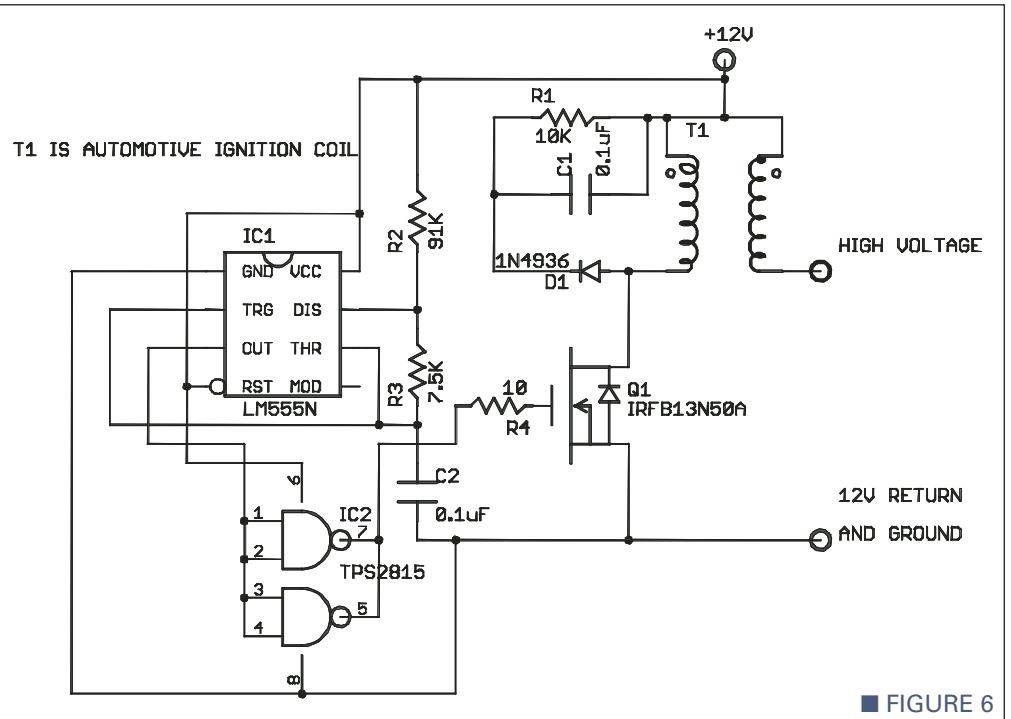
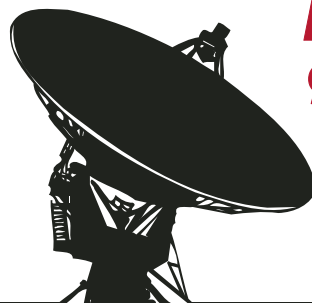


FIGURE 6

atmospheric pressure. In Figure 6, I have modified the design to run at 133 Hz with 0.5 ms on time. The

voltage on C1 should be around 300 volts; if it is lower, raise the value of R1. **NV**



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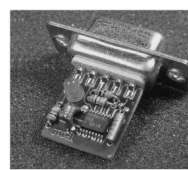


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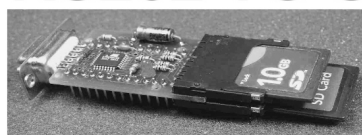


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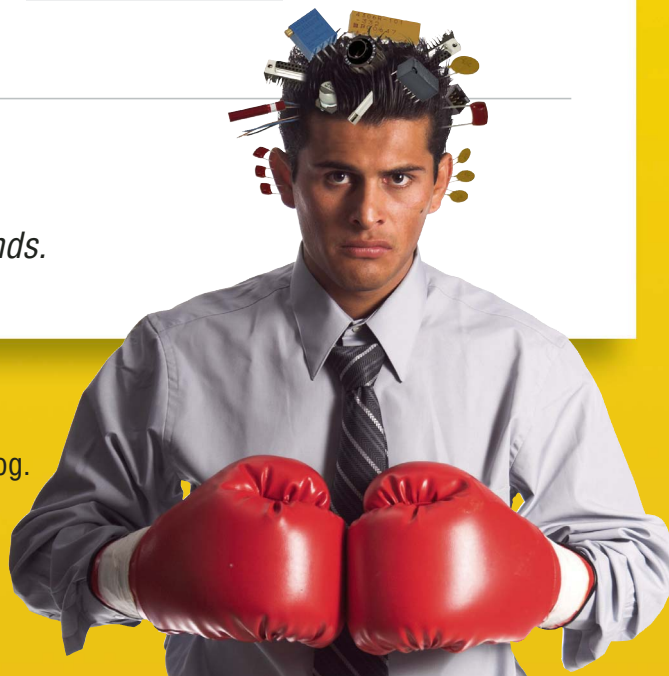
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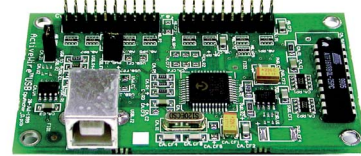


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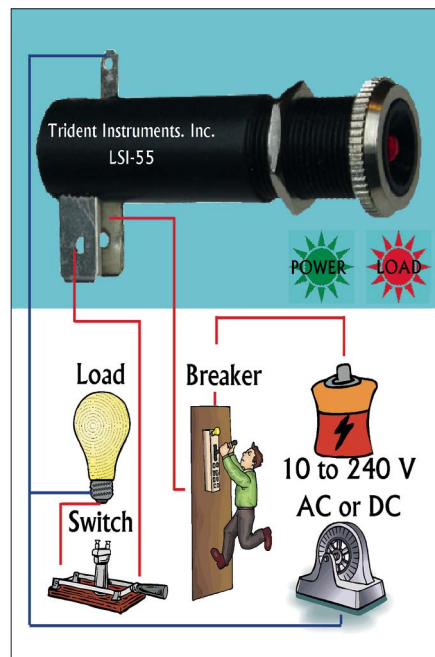
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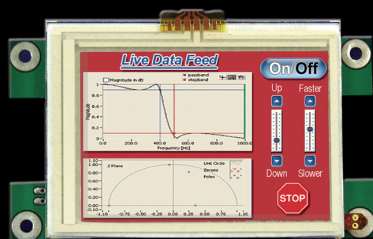
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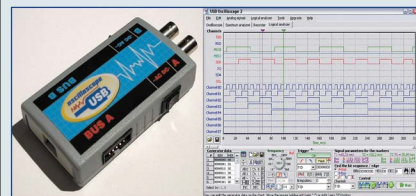
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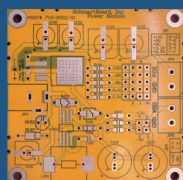
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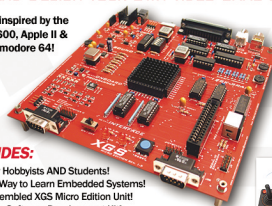


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■ THIS MONTH'S PROJECTS

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■ LEVEL RATING SYSTEM

To find out the level of difficulty for each of these projects, turn to our ratings for the answers.

- Beginner Level
- Intermediate Level
- Advanced Level
- Professional Level

I have always had an interest in animation and time lapse photography. With a digital camera, I found that making time lapse movies became fun and economical.

Time lapse photography is the process of taking pictures at regular intervals.

When you combine the pictures in sequence, they create a movie.

FIELD PROGRAMMABLE INTERVALOMETER

For instance, set up a camera to take two pictures of a blooming flower every minute for three hours. Convert the resulting 360 photographs to an MPEG movie, and watch the flower bloom in under a half minute. I made short time-lapse movies of a moon rise and my drive to work. But after swatting

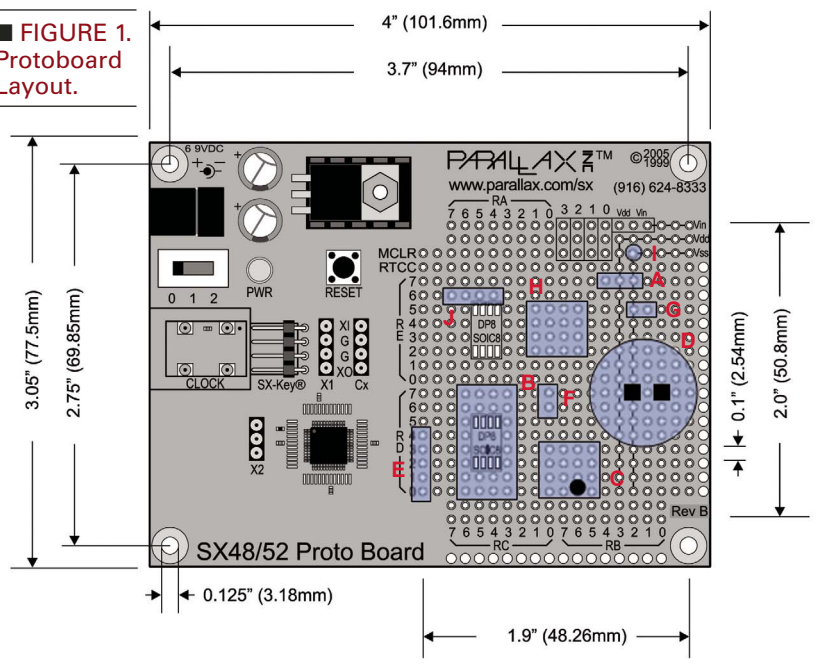
mosquitoes and driving distracted, I realized I needed to automate.

Initial Investigations

I reviewed the remote control available for my Panasonic DMC-FZ20, but I wasn't impressed with a switch on a wire. As I searched the Internet for ideas, I found a resistor array schematic that controls the camera through its remote jack on www.steves-digicams.com — a good start. I also found information about intervalometer functions on Nikon cameras. An intervalometer signals the camera to take a picture at regular intervals.

- A. LCD Display Connector
- B. Component Carrier
- C. Date/Time Chip
- D. Back-up Supply
- E. Switch Connector Block
- F. Camera Control Connector
- G. LED Connector
- H. Optoisolators
- I. Ground Pin for Switch
- J. Resistor for LED

■ FIGURE 1. Protoboard Layout.



I Googled “intervalometer” and found a few commercially built units. Many were for laboratory use, and a few were for specific cameras. The most intriguing and flexible was the Time Machine (www.bmumford.com/photo/camctrl.html). It had great features including motion sensor inputs, and a range of interval setups from simple to complex. However, it did not interface to my camera and was more than I wanted. Something about the Time Machine’s package reminded me that I had built a cookie timer with a BASIC Stamp a few years ago.

At the Parallax website, I reviewed the BASIC Stamp, but thought I might require more program space and memory for my project. This led me to consider the SX microcontroller. After I read about other SX projects, I felt that it would be a platform I could use now and in the future! In addition to a free compiler, the price for the prototyping board made it very attractive to start experimenting.

Design Approach

In addition to setting the interval between pictures, I wanted to specify when to start and stop taking pictures. I also wanted to program these functions in the field.

The number of pictures — or frames — per time period varies based on the event. Longer events, such as a change in season, require one frame per day where a blooming flower requires two frames per minute (frames/min). I planned to use the intervalometer for events that last from 24 to 48 hours so I specified the slowest rate as one frame per minute. My camera required some time to recover between pictures, so my highest rate was 20 frames/min.

In some cases, I wanted to start

	Budget	Measured
Intervalometer	131 mA	108 mA
Intervalometer (picture triggered)	201 mA	125 mA

taking pictures at a certain time of day and stop a few hours later. For example, the intervalometer should start triggering pictures of a sunrise at 4 AM and stop at 8 AM. With a timed session, I could set the start time the night before. When I return the next morning, the camera and intervalometer would have captured the sunrise (I called this the Delay mode). In addition, I wanted to be able to start taking pictures immediately and continue for a set period of time (I called this the Now mode).

In order to make my intervalometer field programmable, I selected a four direction switch and an LCD screen. I used the switch to navigate and select options from a menu presented on the screen.

The final design included a Parallax SX-48, a DS1302 Real Time Clock (RTC) with battery back-up, optocouplers, and menu-driven interface presented on a screen. I considered using the SX-48’s real time clock counter for timed sessions. This would have required some familiarity with interrupts. Since this was my first project with the SX-48, I decided to use the RTC.

After completing the design, I placed a graphic of the SX-48 Protoboard into a Word document. Using items from

■ **FIGURE 2. Power Budget.** I estimated the power consumption from specifications of the components. At the end of the project, I measured the power consumption.

the Word Drawing toolbar, I laid out components onto the graphic. When I was done, I was confident they would fit on the Protoboard (see Figure 1).

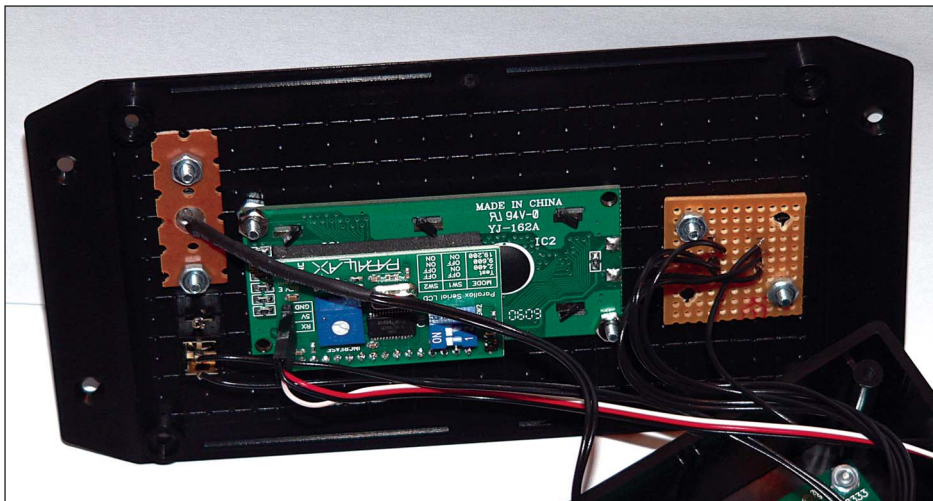
As a final step before starting, I estimated power requirements. When the project was complete, I measured the current required for the circuit quiescently and in operation. The results are in Figure 2.

Circuit Construction

I believe in breaking down a large project into small chunks. For the circuit construction, I installed components on the Protoboard and made a few small programs to help evaluate their operation. The simplest place to start was the LCD. By having a working display, I thought I would also be able to resolve programming issues by displaying information as the program executed.

I soldered a three pin header to the Protoboard so that power and ground pins lined up with the Vdd and Vss bus lines; a third pin would be used to com-

■ **FIGURE 3.** The back of the front panel shows how the four-direction switch was mounted. When the intervalometer was complete, I thought the switch connections should have had heat shrink tubing to help reduce stress.





Set Up	The Set Up sub menu provides for setting the start and stop time for the Delay mode, the duration in minutes for the Now mode, the frames/min, and setting the time and date of the RealTime Clock. The navigation switch moves the cursor on the screen to indicate what is under edit. It also adjusts the value of the parameter. Pushing the navigation switch exits the edit mode and saves the value.
Run	The Run sub menu provides for automatic or manual operation. Manual operation focuses or triggers the camera from the front panel. Automatic operation starts the Delay or Now mode, or cancels a mode in operation.
Options	The Options sub menu provides for toggling the use of an LED during a session (the LED lights when a frame is triggered), toggling the backlight of the LCD Display, and toggling the Super Cap charging circuit.
Power Down	The Power Down item places the intervalometer in Sleep mode. The power switch must be cycled to display the main menu again.

municate with the LCD. After I verified the LCD operation, I connected a microcontroller port pin to the third pin on the pin header, and verified that I could write text to the display. But I discovered that the text started wrapping after 20 characters rather than 16. Parallax Support said I should remove a surface mount jumper from the back of the LCD PC board. With this fix, the display wrapped the text correctly.

With the LCD in place, I wanted to display the time of day using the RTC. I soldered it and its crystal to the Protoboard. I completed the connections from the SX-48 to the RTC, and ported a BASIC Stamp program to S/X Basic. The program initialized and displayed the time on the LCD.

At first, the time did not appear because the RTC was initialized incorrectly. The syntax was correct for the BASIC Stamp but not for the SX-48 (the compiler did not detect the syntax errors). The Parallax online discussion Forum helped me correct the program. I was relieved to see the RTC operating because I thought I had burned it or the crystal when I soldered them to the board!

To complete the RTC development, I soldered a Super Cap to the Protoboard. I added code to my program to operate a charging function through the RTC. I have found that the RTC accurately maintains the time and date for more than a month on just the Super Cap current.

I selected an ALPS four direction switch with center push for menu navigation. Since the small switch had no mounting fixtures, I mounted it to a one inch square piece of Vectorboard.

I enlarged some of the holes, and mounted the switch in the center. I drilled a hole in each corner, and used two of them to mount the Vectorboard with the switch on the front panel of my enclosure (see Figure 3).

I verified the switch operation with a program that displayed the closed connection on the LCD. I placed all of the switch connections on a single port of the microcontroller. In this manner, I only have to read the port, mask the reading, and compare the result to constants in order to determine the position of the switch.

Firmware Development

I prefer to develop programs in small steps to both gain confidence in the system and to minimize code defects. When there is a defect, then I have only to look at the most recent changes to correct it. As the program grew in size, I found that locating defects, in some cases, was a little more difficult as more parts of the program interacted.

The main loop of the program monitors the four position switch. The up and down switch positions navigate the menu like a Windows list box. The left and right positions move between menu levels and select menu items, respectively. I used the push button connection to finalize editing of parameters.

I found it challenging to detect a number less than zero. For example, the index of the current menu item is zero and I want to navigate up. The program decrements the index and its value becomes 255. The SX-48 does not recognize the value as -1, and the following SX/BASIC statement did not

■ **FIGURE 4. Intervalometer Operation.** After turning it on, the intervalometer presents the main menu. The menu items and their functionality appear in the table here.

evaluate to true:

```
IF MenuIndex < 0 THEN
```

When I needed to detect a negative number, I checked for 255 explicitly. Fortunately, I did not have a case where 255 was a valid value for any of my indexes. Once I recognized this, I was comfortable adopting it as a standard for this project. I would not recommend it for all projects.

As I started adding more functionality, I found odd things happening on the display. The cursor would be in the wrong place or a value would not display correctly. For example, when editing frames per minute, I wanted to write "Frames/min" and "10" on the first line, and clear the second line. The label would appear but the value did not.

When I stepped through the program, I discovered that it wrote the label on the first line, the value on the second line, and then cleared the second line. I was not able to see this under normal execution because it happened so quickly. The debugger was a valuable tool to help resolve this issue.

As the code grew larger, I noticed that the menu text was not displaying correctly. I reviewed the S/X BASIC READ command that helps move the text to the display. The command expects to find menu text on a single page of 256 bytes. My menu data crossed a page boundary, and was more than 256 bytes. To resolve this, I moved the menu text to its own file and gave it a starting point on a page boundary. Also, my menu became simpler (and smaller) which focused the program on basic intervalometer functions.

I completed the programming for editing parameters and started working on the camera interface. In addition to a resistor array, I added a set of optocouplers (one for focus and one to trigger the picture). The optocouplers isolate the power supply of

■ **FIGURE 5. The Completed Project.**

the camera from the intervalometer.

I proved the interface operation on a breadboard by placing the resistors on a DIP header. On the breadboard, the camera operated correctly. I inserted the DIP header on the Protoboard and connected the optocouplers. Disappointingly, the camera did not react.

I reviewed the interface circuit and the placement of the DIP header on the Protoboard. In that exact spot, the Protoboard had holes shorted by design. This was causing a short in my resistor array. I changed the resistors on the DIP to take advantage of the Protoboard design. With corrections in place, the camera operated as expected.

My final programming task was to place time intervals between frames. The SX-48 on-board timers seemed an obvious choice. My first approach was to monitor the number of timeouts on a timer, and trigger the camera when the timeouts equaled a pre-calculated count. I was starting to run low on code space, so I designed a more efficient solution.

I set up Timer1 in pulse width mode (50% duty) and the other, Timer2, in External Trigger mode. The pulse from Timer1 triggers Timer2. Next, I set the Timer2's compare register to the number of pulses I needed before I wanted a frame triggered. When the number of counts was the same as the compare register, the SX-48 generated an interrupt. The code in my interrupt routine became very simple: reset Timer2 and trigger the camera.

Code Optimizations

I made changes to subroutines which freed up code space and helped me add extra, unexpected functionality. These changes included code reuse, my own PAUSE command, display optimizations, and removing functionality.

I saved code space when I wrote code that could be reused. For exam-



ple, I needed to set the date and time of the Real Time Chip and for the Delay mode. I wrote the subroutine that sets the date and time generically so that the settings could be used for either. I also reused camera control subroutines for both manual and automatic operation.

SystemPause

The SX/B PAUSE command compiles to a few lines of assembly everywhere it's used. I copied the assembly code of the PAUSE command to a single SX/B subroutine — named SystemPause — and passed in a single argument. The argument set the number of milliseconds to pause. The overhead of calling into and returning from my subroutine was not critical in my application, and I saved code space.

Display Optimization

I needed to indicate the operational status on the display. Custom characters required code space, so it was more economical to use existing characters. Also, I found that I could manipulate the displayed character with masking to indicate different status. For example, the \$ character has a binary value of 00100101. By manipulating the byte

that stores this value, I could change it from 00100000 (space) to 00100101 by changing two bits. On the display, the status toggles between 'space' and '\$.'

Removing Functionality

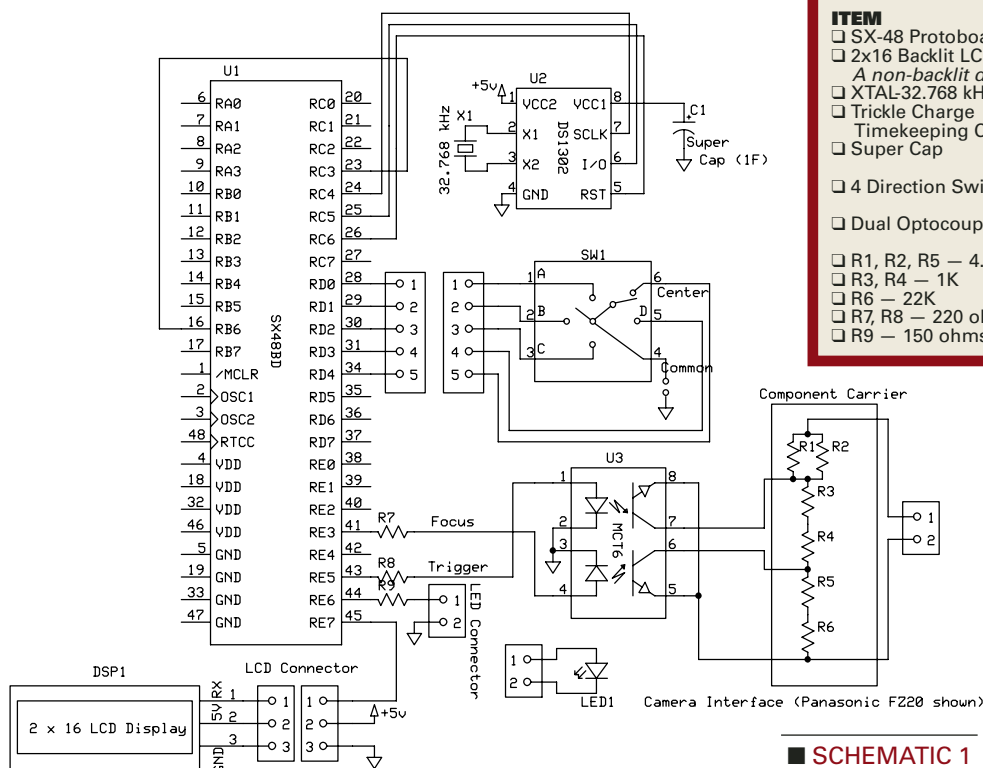
I wrote a subroutine to turn off the display when the intervalometer was waiting to start in Delay mode. When I made current measurements, I found there was very little difference between the display on and off — the LCD still required power. I removed the code and reclaimed the code space for features that made more sense. For example, when setting a date, I didn't check for a valid end of month date. With the extra code space, I checked for things like February 31st and prevented them. Also, I provided for an automatic power-down after two minutes of navigation inactivity.

Testing

Figure 4 describes all of the menu functionality in the intervalometer. I verified most of it on the bench. With the intervalometer complete (see Figure 5), I needed a beta test. Since my "project manager" wanted me to

■ **FIGURE 6. Project Alternatives.** Here are a few alternatives to the project presented here.

The NE555 Timer	Set up the timer in astable mode. A combination of decade counters (4017) and ripple counters (4020 or 4040) would provide a range of intervals. Make sure the timer pulse width is wide enough for the camera or interface circuit to detect.
The Nikon Coolpix S50C	This model has the intervalometer function built in.
Use your Personal Computer	Most Canon PowerShot models include software which controls the camera through its USB port. The software includes an intervalometer function.



ITEM	SUPPLIER/PART NO.
<input type="checkbox"/> SX-48 Protoboard	Parallax/45300
<input type="checkbox"/> 2x16 Backlit LCD Display	Parallax/27977
<i>A non-backlit display will work just as well.</i>	
<input type="checkbox"/> XTAL-32.768 kHz	Parallax/251-03230
<input type="checkbox"/> Trickle Charge Timekeeping Chip	Dallas Semiconductor/DS1302;
<input type="checkbox"/> Super Cap	Parallax/604-00005
	Elna/DB-5R5D105;
	Mouser/555-1.0Z5.5
<input type="checkbox"/> 4 Direction Switch	ALPS: SKQUCAA010;
<input type="checkbox"/> Dual Optocoupler	Mouser/688-SKQUCA
	Fairchild Semiconductor/MCT6;
	Mouser/512-MCT6
<input type="checkbox"/> R1, R2, R5 — 4.7K	
<input type="checkbox"/> R3, R4 — 1K	
<input type="checkbox"/> R6 — 22K	
<input type="checkbox"/> R7, R8 — 220 ohms	
<input type="checkbox"/> R9 — 150 ohms	

■ SCHEMATIC 1

paint the kitchen, I set up my camera to film it. I used the Now mode of the intervalometer. In this mode, the intervalometer starts triggering pictures immediately, and continues for four hours. After an hour, a defect caused the triggering to stop.

After debugging through the code, I found that I was using a variable twice which affected the calculation for the Now mode. After making a correction, the intervalometer

operated the entire four hours.

I discovered one last defect when setting the date and time. It was difficult to track down because I was using an index to write to memory. The index was one greater than it should have been, and this affected how information was displayed. When I corrected the index, the defect was resolved.

Going Farther

Instead of using elapsed time to trigger frames, the intervalometer could be modified to accept motion sensor information. In this manner, the intervalometer waits until the sensor detects motion, and then takes a picture. This could be used for photographing wildlife in remote places.

Many cameras have a USB port which provides for remote operation. The intervalometer could be modified to support a USB interface with the addition of commercially available integrated circuits. While this would involve hardware and firmware changes, the intervalometer would support a wider range of cameras. **NV**

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SOUTHERN CALIFORNIA * TAMPA * TORONTO

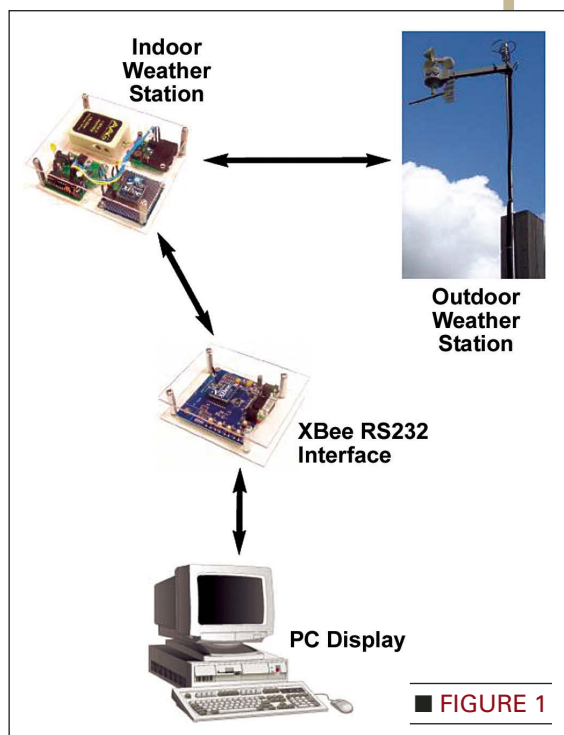
PORTLAND * SAN JOSE * SEATTLE



In the last three installments, you built the three satellites shown in Figure 2. I showed you how to transmit and collect basic data.

In this final installment, I am going to detail the protocol that I created that will allow you to transmit various readings.

These readings can be weather related, or from various other pieces of telemetry you may want to add to the mesh network.



CONTROL YOUR WORLD

Build a Wireless Weather System: Part 4

The reason I created a special protocol instead of just sending text messages was so that simple telemetry messages could be sent to any device. You will be able to add any kind of display system and pick out just the messages you are interested in.

The Wireless Weather Protocol

The basic protocol format in its simplest form is shown in Table 1. The first byte in the packet is the Start Of Packet (SOP). This is always a value of 2. The SOP byte is followed by the packet size. The packet size is the number of bytes that follow. The remaining bytes are the actual data bytes followed by a two byte checksum.

There are some additional rules that must be followed:

- **RULE 1:** There must always be at least two data bytes and

two checksum bytes for a packet size of four. More are okay, but no less.

- **RULE 2:** If any of the data byte values are 0-3, then they are preceded by a 3. The value is then added to 100. For example, a value of 1 would be represented as 3,101

- **RULE 3:** If either byte in the checksum is less than 4, it is added to 100. Note that unlike the data bytes, the checksum bytes will not be preceded by a 3 when this happens.

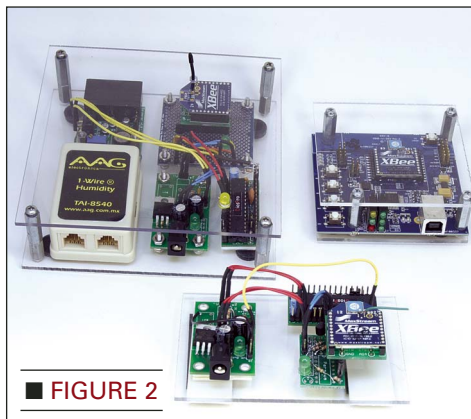
While this may sound a little like overkill, it does solve a few potential problems.

- 1) If a satellite is started, it won't start looking at any packets until it gets a true valid SOP.

- 2) If a collision takes place between two satellites, the checksum won't match and the message will be discarded.

- 3) If any message gets corrupted, it will be discarded.

One other point I need to make is that I set the baud rate to 9600. Originally, I wanted to use 115200 as the baud rate, but the XBee modules had a problem with the actual timing needed to



duplicate this baud rate.

To make life easier, I have created both packet builder and decoder functions in Zeus for the Pocket PC and desktop, as well as functions for the DiosPro chips.

Let's try a little experiment by using the indoor satellite to transmit a message to the PC satellite.

- **STEP 1:** Power down the outdoor satellite. This will keep it from interfering with our protocol test. Program the Indoor Weather Satellite with the Dios code shown in Program 1 (DiosPacketSend.txt). The main program calls the sendWpacket function once every five seconds. The sendWpacket function is the heart of the program. You pass from two to 16 data bytes and the function will build and transmit a weather packet for you. I also included a couple of print statements so the debug window

will report the bytes in the packet that are sent as shown in Figure 3.

- **STEP 2:** Now load up a copy of ZeusPro and load the code shown in Program 2 (ZeusRX Packet.txt). You will need to change the com port to that of your X-CTU (PC satellite). Once you compile and run the

Byte	Example	Description
1	2	Start of packet indicator
2	8	Number of bytes to follow
3	100	Data byte
4	101	Data byte
5	102	Data byte
6	103	Data byte
7	104	Data byte
8	105	Data byte
9 & 10	111 & 102	Two byte checksum

■ TABLE 1

PROGRAM 1

```

DiosPro
'DiosPacketSend.txt
'Packet Test Program
func main()
    hsersetup baud,HBAUD9600,start,txon,inwait,500

loop:
    print "Send"
    sendWpacket(100,101,102,103,104,105)
    print
    pause 5000
    goto loop

endfunc

'_____
'Send a Weather Packet
' Pass
'   up to 16 bytes.  Each byte must be value of 0-255
'_____

func sendWpacket(x1,x2,x3,x4,x5,x6,x7,x8,x9,x10,x11,x12,x13,x14,x15,x16)
    dim sum as integer
    dim x as integer
    dim dat as integer
    dim ct as integer
    dim ect as integer
    ct = OPP8
    sum = 0
    ect = 0

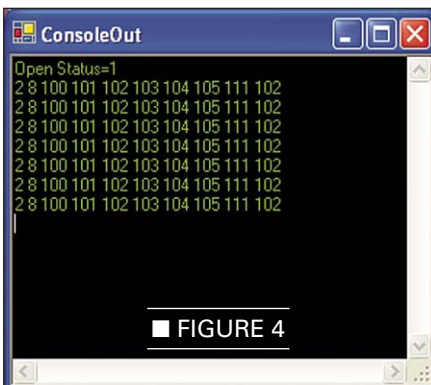
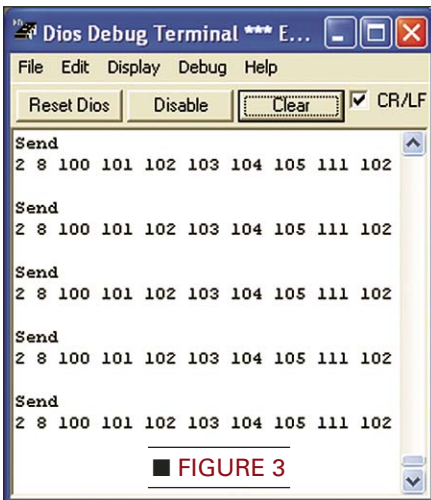
    if ct < 2 or ct > 16 then
        print "Invalid Number of Data bytes.  Send 2-16"
        exit 0
    endif

    'First see how many escapes
    for x = 0 to ct - 1
        dat = x1(x)
        if dat < 4 then
            inc ect
        endif
    next

    sum = sum + ct+2+ect
    hserout 2,ct+2+ect

```

continued ...





Program 1 continued ...

```

print 2," ",ct+2+ect," ";
for x = 0 to ct - 1
    dat=x1(x)
    sum = sum + dat
    if dat < 4 then
        sum = sum + 3 + 100
        hserout 3,dat+100
        print 3," ",dat+100," ";
    else
        hserout dat
        print dat," ";
    endif
next

if sum.byte(0) < 4 then sum.byte(0) = sum.byte(0)+100
if sum.byte(1) < 4 then sum.byte(1) = sum.byte(1)+100
hserout sum.byte(0),sum.byte(1)
print sum.byte(0)," ",sum.byte(1)
exit 1
endfunc

```

PROGRAM 2

```

'Zeus Receive packet test
'ZeusRXPacket.txt
func main()
    dim x as integer
    dim tstr as string

    x=ComOpen(1,baud=9600,port=5) ' <--- Set Com Port here
    print "Open Status=";x
    ComBGSuspend(1,0)

loop:
    sleep(1)
    doevents()
    tstr = getweatherpacket()
    goto loop

endfunc

'-----
' This looks for a single packet of data.
' Returns empty string if no or bad packet
' Returns packet inside string if success
'-----
func getweatherpacket() as string
    dim sum as integer
    dim state as integer
    dim count as integer
    dim plen as integer
    dim dat as integer
    dim byte0 as integer
    dim byte1 as integer
    dim sbyte0 as integer
    dim sbyte1 as integer
    dim x as integer
    dim tstr as string
    tstr=""

    x=ComWaitforByte(1,100)
    if x <> 2 then exit("")
    print 2+" ";

```

continued ...

program, you should see the bytes received by each packet as shown in Figure 4. This program calls the function called `getweatherpacket`. In Zeus, the `getweatherpacket` function returns a string containing the packet data bytes.

There is a bit more needed in order to put the protocol to work in our network. The first two data bytes have been predefined as detailed in Table 2. The data field is the sending satellite ID. Each satellite will have a unique ID that you will assign. In the case of our Indoor Weather Satellite, it is 30. When a display device decodes the receive packet, it will be possible to tell where the signal is coming from. The second data field is the type of reading. This value is important as it tells the display satellite the kind of data that is coming.

Let's take our experiment to the next level.

- **STEP 3:** Program the Indoor Weather Satellite with the Dios code shown in Program 3 (DiosSend Temp.txt). In this program, we take a 1-Wire temperature reading from the DS1820. The result is passed to the `sendWpacket` function. We send our fromid and the reading type of 72. We then send all four bytes that make up the floating point temperature.

There are a few things you need to know in order for this program to work. First, make sure the DS1820 is plugged into the satellite as outlined in Part 2 of this series. You then need to program the `IndoorNetworksearch.txt` program into the DiosPro. This program will display all the network 1-Wire serial numbers (ROMs) connected to the satellite as shown in Figure 5. The reading we are interested in for this test is the DS1820 Thermometer. Use that reading to populate the eight hex numbers in the table command at the top of Program 3. One other thing to keep in mind is that I added a bit of code to pull port 13 high because we use that port to supply 5V to the 1-Wire network.

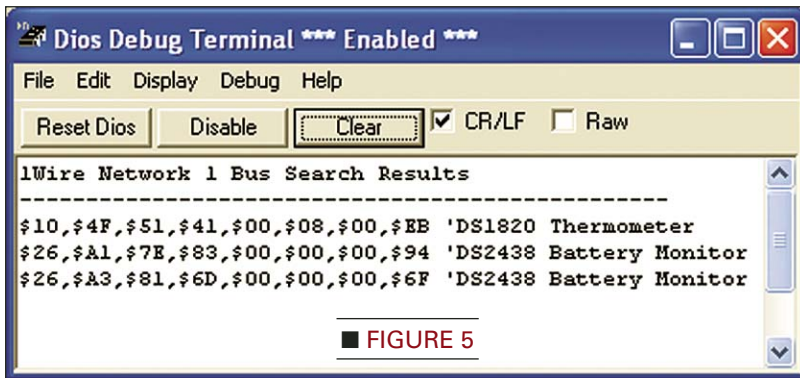


FIGURE 5

• **STEP 4:** Load up the program ZeusRXTemp.txt into Zeus Pro and compile the program. The program is rather large so the listing in Program 1 only represents the most important portions of the code. In this program, we make a call to the

getweatherpacket function. If a packet of data is received, a call to the procweatherpacket function is called. This function parses the packet data and pulls the transmitting satellite ID and reading type and places them in the fromid and cmd variables.

A test is then performed to see if the reading type is 72 (Indoor Temp). If it is, the four floating point bytes are pulled out. Floating point variables on the PC are not stored the same way as they are on the DiosPro, so a call to the DiostoPCfloat function is made to convert those four bytes to a single precision floating point compatible with the PC. Finally, a call is made to convert the DS1820's Celsius reading to Fahrenheit. The data is then displayed using the print command.

This is how all readings are parsed. Once parsed, it's up to the particular satellite display program to utilize this data and convert it into the appropriate format so that it can be used.

Indoor Weather Satellite Firmware

The program called Indoor Weather.txt program takes three

Data Field	Byte	Description
1	3	Satellite ID of sender
2	4	Reading type
3	5	Data byte 1
4	6	Data byte 2
5	7	Data byte 3
6	8	Data byte 4

TABLE 2

readings: indoor humidity, barometer, and indoor temperature. An internal timer is set up to count milliseconds and each reading is taken at one minute intervals. As each reading is taken, the packet is sent. Once all four readings are taken, a status packet is sent. Take a look at the beginning of this program and you will see a definition of each reading packet that is sent.

Again you will need to populate the ROM tables at the start of the program with the ones that map to your particular 1-Wire devices.

Outdoor Weather Satellite Firmware

The program called Outdoor weather.txt works much the same way as the indoor program. The major difference is the number and type of sensors that are read. There is also processing done to calculate the wind speed variations. My particular

Program 2 continued ...

```

'Get packet Length
plen = ComWaitforByte(1,5000)
if plen = -1 then
    print "Len Error"
    exit("")
endif

print plen+" ";

sum = plen
for x = 1 to plen
    dat = ComWaitforByte(1,5000)
    if dat = -1 then
        print "Byte Error ",x
        exit("")
    endif
    print dat+" ";

    if x < plen - 1 then
        sum = sum + dat
    endif

    if state = 1 then
        state = 0
        dat = dat - 100
        tstr = tstr + chr(dat)
        goto cont
    endif

    if dat = 3 then
        state = 1
    else
        tstr = tstr + chr(dat)
    endif
endif

cont:
next

print
'print sum
byte0 = sum & 255
if byte0 < 4 then byte0 = byte0+100
byte1 = sum & 65280 / 256
if byte1 < 4 then byte1 = byte1+100
'print byte0,byte1
sbyte0 = asc(mid(tstr,len(tstr)-1,1))
sbyte1 = asc(mid(tstr,len(tstr),1))
'print sbyte0,sbyte1
if byte0 <> sbyte0 or byte1 <> sbyte1 then
    print "Sum Error"
    exit("")
else
    exit(left(tstr,len(tstr)-2))
endif
endfunc
  
```

outdoor satellite monitor is an AAG wind speed and wind direction sensor. It monitors a temperature sensor (DS1820) and a humidity sensor. It watches a Hobby Board humidity gauge. It also takes four 10 bit A-to-D (analog-to-digital) readings



PROGRAM 3

```

DiosPro
'DiosSendTemp.txt
'Send the Indoor Temp from Indoor Weather Satellite
func main()

    table InTEMPROM: $10,$4F,$51,$41,$00,$08,$00,$EB 'DS1820 Thermometer
    gconst fromid 30 'MY ID.

    gconst ownw1port 12 'Port for 1Wire Network 1
    'Port 13 used for 1K pullup
    output 13
    high 13
    pause 100

    global temperature as float

    hsersetup baud,HBAUD9600,start,txon,inwait,500

loop:
    temperature = DS1820readtemp(ownw1port,3,InTEMPROM)
    print "Send Temp of ",temperature
    sendWpacket(fromid,72,temperature.byte(0),temperature.byte(1),_
                temperature.byte(2),temperature.byte(3))
    pause 5000
    goto loop

endfunc

'-----
'Send a Weather Packet
' Pass
' up to 16 bytes. Each byte must be value of 0-255
'-----
func sendWpacket(x1,x2,x3,x4,x5,x6,x7,x8,x9,x10,x11,x12,x13,x14,x15,x16)
    dim sum as integer
    dim x as integer
    dim dat as integer
    dim ct as integer
    dim ect as integer
    ct = OPP8
    sum = 0
    ect = 0

    'First see how many escapes
    for x = 0 to ct - 1
        dat = x1(x)
        if dat < 4 then
            inc ect
        endif
    next
    if ct < 2 or ct > 16 then
        print "Invalid Number of Data bytes. Send 2-16"
        exit 0
    endif

    sum = sum + ct+2+ect
    hserout 2,ct+2+ect
    print 2," ",ct+2+ect," ";
    for x = 0 to ct - 1
        dat=x1(x)
        sum = sum + dat
        if dat < 4 then
            sum = sum + 3 + 100
            hserout 3,dat+100
            print 3," ",dat+100," ";
        else
            hserout dat
            print dat," ";
        endif
    next

```

continued ...

and has a modified rain gauge.

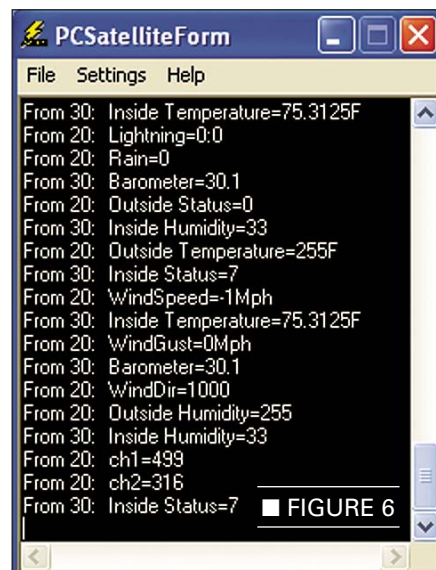
All the code to handle and display these sensors is included in the outdoor and PC satellite software. Even if you don't utilize them, they will send empty packets so you can just ignore the data.

There is quite a bit of program code associated with this program. Several libraries are included in the download. They consist of the following libraries:

- WLhum.lib
- WLrain.lib
- WLtemp.lib
- Wldir.lib
- WLight.lib
- Wlspeed.lib
- Wltimers.lib

PC Monitor Satellite

On the PC side, I have included a program called PCSatellite.txt. This program can handle several reading types from both the indoor and outdoor satellites. I have included a special version called PCSatellite Form.txt that allows you to select the com port. I have also included a compiled version of the form version so you don't have to worry about programming the code. The output for both programs is shown in Figure 6. In this particular example, I don't have any sensors connected to



the Outdoor Satellite, so it shows empty packets.

Final Thoughts

I have been asked by a few individuals about the MaxStream XBee Series 2 modules. I have not been able to get my hands on any of these, but I can tell you that they will not work with this project without certain code modifications, nor are they compatible with the original XBee series.

I have purchased an XBee Pro module and hope to add it to my network as the coordinator. The Pro module has much more range than the standard modules. It also has a much more sensitive receiver, so I should be able to extend my network by adding just one of these to it. Once I do, I hope to provide some updates on the Kronos Robotics website.

I built the following satellites for my weather station:

- LCD Display
- LED Sign
- Wood Stove Monitor
- X10 Interfaces

I plan on offering these as future articles as time permits.

Be sure to check for updates at www.kronosrobotics.com/Projects/wirelessweather.shtml. **NV**

LINKS

■ **Hobby Boards**
www.hobby-boards.com

■ **SparkFun Electronics**
www.sparkfun.com

■ **Kronos Robotics**
www.kronosrobotics.com/xcart/customer/home.php

■ **SchmartBoard**
www.schmartboard.com/index.asp?a=11&page=a_products

■ **Jameco Electronics**
www.jameco.com

Program 3 continued ...

```
if sum.byte(0) < 4 then sum.byte(0) = sum.byte(0)+100
if sum.byte(1) < 4 then sum.byte(1) = sum.byte(1)+100
hserout sum.byte(0),sum.byte(1)
print sum.byte(0)," ",sum.byte(1)
exit 1
endfunc
```

```
include \lib\Dios1820.lib
```

PROGRAM 4

```
'Zeus Receive Indoor Temperature
'ZeusRXTemp.txt
func main()
  dim x as integer
  dim tstr as string

  x=ComOpen(1,baud=9600,port=8) '← Set Com Port here
  print "Open Status=";x
  ComBGSuspend(1,0)

loop:
  sleep(1)
  doevents()
  tstr = getweatherpacket()
  strif tstr <> "" then
    procweatherpacket(tstr)
  endif
  goto loop

endfunc

'_____
'Main Weather Processor
'_____

func procweatherpacket(tstr as string) as integer
  dim b0 as integer
  dim b1 as integer
  dim b2 as integer
  dim b3 as integer

  dim slen as integer
  slen = len(tstr)
  if slen < 2 then exit(0)

  global cmd as integer
  global fromid as integer

  '← Weather Variables
  global itemperature as float

  fromid = asc(mid(tstr,1,1))
  cmd = asc(mid(tstr,2,1))

  '← Test for the reading type
  select integer cmd
  case 72
    b0 = asc(mid(tstr,3,1))
    b1 = asc(mid(tstr,4,1))
    b2 = asc(mid(tstr,5,1))
    b3 = asc(mid(tstr,6,1))
    otemperature= cvtDiosToPCfloat(b3,b2,b1,b0)
    if otemperature <> 255 then otemperature = 1.8 * otemperature + 32
    print "From "+fromid+": ", "Inside Temperature="+otemperature+"F"
  endselect

endfunc
```


PARTS LIST

The following is a breakdown of the sources for all the components needed for Parts 1 and 4 of this project.

HOBBY BOARDS

□ Wind Instrument

www.hobbyboards.com/catalog/product_info.php?cPath=22&products_id=92

□ Humidity Module (H3-R1-A)

www.hobbyboards.com/catalog/product_info.php?cPath=22&products_id=46

□ Lightning Detector

www.hobbyboards.com/catalog/product_info.php?cPath=22&products_id=65

SPARK FUN ELECTRONICS

□ XBee Breakout Board (Used to build various interface boards)

www.sparkfun.com/commerce/product_info.php?products_id=8276

□ 2 mm connectors (You need two for each Breakout board)

www.sparkfun.com/commerce/product_info.php?products_id=8272

KRONOS ROBOTICS

□ DiosPro 28 chip

www.kronosrobotics.com/xcart/cus_tomer/product.php?productid=16429

□ Dios Carrier 1

www.kronosrobotics.com/xcart/cus_tomer/product.php?productid=16170

□ 3.3V to 5V Interface Kit

www.kronosrobotics.com/xcart/cus_tomer/product.php?productid=16537

□ 40-Pin Male Header

www.kronosrobotics.com/xcart/cus_tomer/product.php?productid=16290

□ 1K resistors

www.kronosrobotics.com/xcart/cus_tomer/product.php?productid=16178

□ Regulator Kit

www.kronosrobotics.com/xcart/cus_tomer/product.php?productid=16304

□ Free Dios Compiler (Includes 1-Wire libraries) www.kronosrobotics.com/downloads/DiosSetup.exe

KRMICROS

□ ZeusPro Compiler

www.krmicros.com/Development/ZeusPro/ZeusPro.htm

SCHMARTBOARD

□ Prototyping board (.1")

www.schmartboard.com/index.asp?a=11&id=24

□ Jumpers 5" Yellow

www.schmartboard.com/index.asp?a=11&id=42

□ Jumpers 3" Red

www.schmartboard.com/index.asp?a=11&id=41

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Scorpion Mini

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Scorpion HX

- ◆ Dual 2.5A (6A pk) H-bridges
- ◆ Plus 12A fwd-only channel
- ◆ 5V - 18V
- ◆ 1.6" x 1.6" x 0.5"



\$119.99

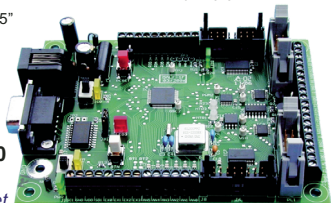
Scorpion XL

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- ◆ 5V - 24V
- ◆ 2.7" x 1.6" x 0.5"

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- ◆ C source for routines provided
- ◆ See www.embeddedelectronics.net

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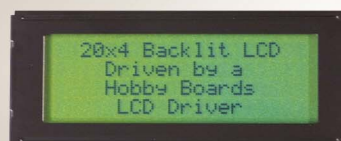


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Cases

Our devices are featured in Wyle's Extreme Tech series Weather Toys by Tim Bitson. This book is available on our website.

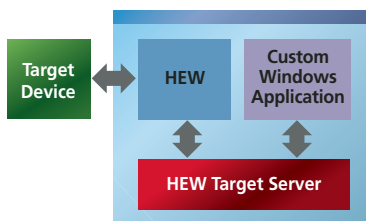


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*While supplies last



Many people love winter because of the snow. I am not — nor do I ever expect to be — one of those people. I was born and raised in the Los Angeles area and am happy to be back after a 10-year stint in Dallas. I really enjoyed Dallas, but in the winter it gets cold; well, to me, anyway, as I consider anything below about 55 degrees to be unbearable. I do enjoy the winter months, though (especially here in SoCal where the temperatures work for my thin blood),

because the winter months bring holiday lights; that's what I look forward to in the winter.

VIXEN

LIGHTS THE WAY

I live in a pretty, suburban neighborhood just a short distance from the famed Walt Disney Studio, and I can tell you that the studio isn't the only place creating magic this winter. Most of the homes near me are beautifully lit and, of course, slow traffic through the neighborhood as holiday gawkers enjoy the displays. That's okay with me, in fact, I think it's okay with most people as it reminds them of the joys and blessings of the season. And what's a better way to unwind from the stresses of shopping than a nice, easy drive through a neighborhood of beautifully lit homes?

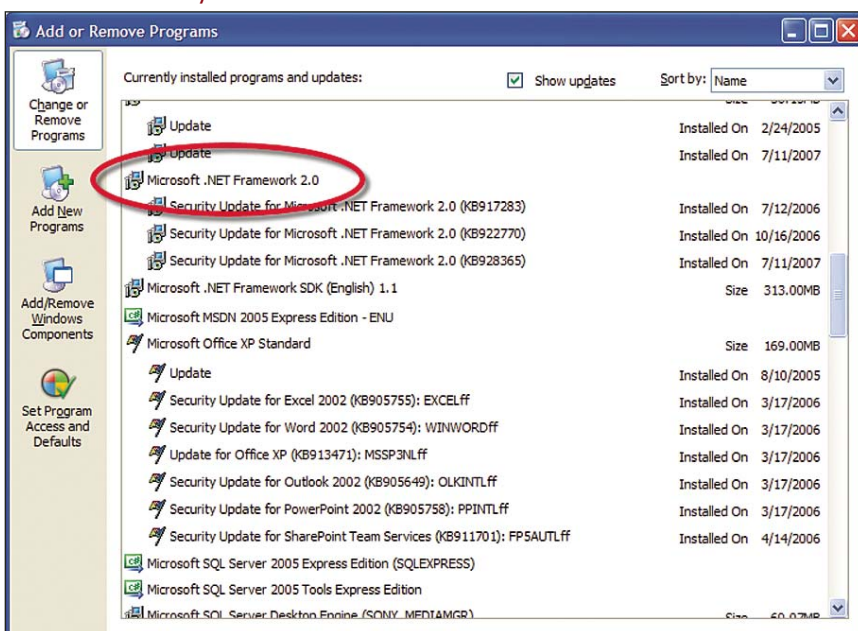
Now, most displays, while gorgeous, will be static. There are those, however, who will step it up a notch, and if you're inclined to take your holiday lighting to a new level

— even if it's just your Christmas tree — this article may prove helpful. A really cool piece of freeware called Vixen can turn your PC into an audio-synchronized lighting controller that will have your neighbors applauding you as you come out to pick up the morning paper.

Installing Vixen

Vixen doesn't come with a traditional installer so I'm going to walk you through the steps to get it up and running on your Windows PC. First things first: Vixen is built using Microsoft's .NET technology and as such requires version 2.0 of the .NET framework to be installed. Checking your system is easy: Open the Control Panel, double-click on Add or Remove Programs, and then

■ FIGURE 1. Verify .NET Framework.



■ FIGURE 2. Install or Upgrade.

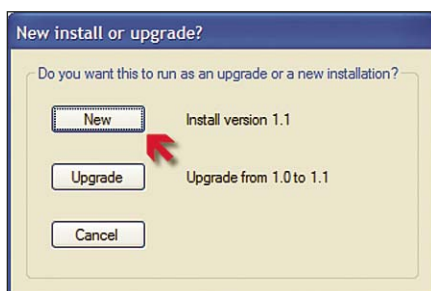
scroll down the list to verify that the framework is installed. Figure 1 shows that I do, in fact, have the correct framework on my PC. If you don't, you can get the installer from Microsoft, and K.C. Oaks (Vixen's creator) has made our lives easy by providing a link to the .NET framework installer on his downloads page.

Once the .NET framework is installed, you can download Vixen; as of this writing, the current version is 1.1.11. The program comes as a ZIP file that contains a custom install tool, the data files for the installer, and text file with release notes. Unzip these files into a temporary folder (you can't run the installer from within the ZIP), open the folder where you placed the files, and then double-click on VixenInstall.exe.

As I previously stated, this is a custom installer. The first dialog you'll see (Figure 2) will ask if this is a new install, or an upgrade from version 1.0. I'm assuming that this is a new install, so you will click on New. The installer wants to place the operational files in a folder just below the current location — but this is probably not where you want them. Even if this isn't a traditional installer (like the commercial programs we're all used to), we can still locate the program files appropriately. On the Location dialog (Figure 3), you'll want to click on the Change This button. You'll be presented with a Windows folder browser.

I suggest that you locate the C:\Program Files folder, click on it, and then click on the Make New Folder button at the bottom of the dialog. Enter Vixen as the folder name and click OK. The Vixen location dialog should now show C:\Program Files\Vixen. Click the Start button to install the program (Figure 4).

What you'll find on looking into the Vixen folder is that the program and several other folders have been installed. What you won't find, howev-



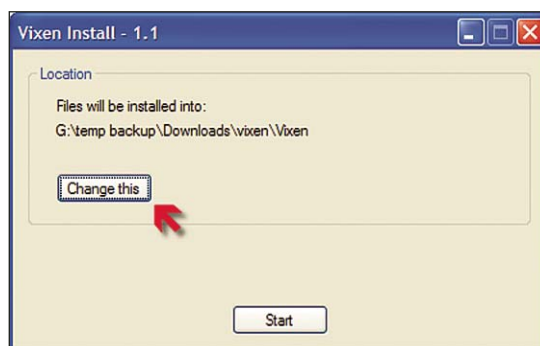
er, is a shortcut on your desktop in your Start menu. Open the Vixen folder in Windows Explorer, find Vixen.exe, then right-click and drag the icon onto your desktop. When you release the mouse button, a context menu will allow you to create a shortcut. Now you're ready to go.

Vixen Basics

In a word, Vixen is a sequencer, primarily intended for lighting control, and when a sequence is active the program will periodically update the lamp control outputs with brightness levels (expressed in percent, 0 to 100). And as lights and music go so well together, we can import a song into a sequence and synchronize the lighting outputs to it — Vixen will play the music and drive the lights simultaneously. How cool is that for a free program?

Learning by doing is far more effective than learning by reading, so let's fire up Vixen and create a little test program to get a grip on how things work. Double-click on the shortcut you created earlier to start Vixen. Don't be surprised by the less-than-audacious startup; you'll get nothing but a blank screen. No worries, just click on the Sequence menu, select New Event Sequence, and then select Standard Sequence. You'll be presented with a wizard to create a sequence. Click on the Next button.

The first page of the wizard lets you set the event timing for the sequence. This value sets the minimum on-time for the

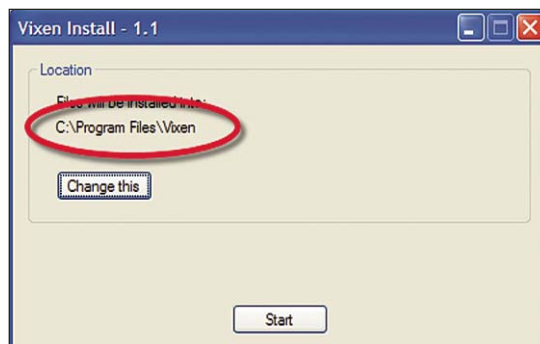


■ FIGURE 3. Install Location.

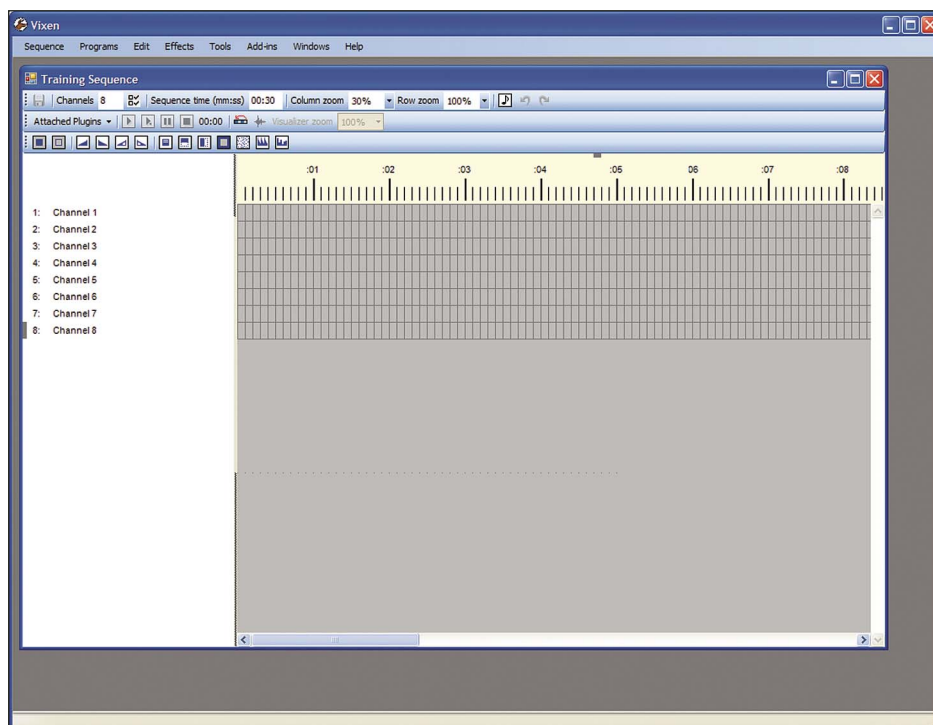
output channels. The default value is 100 (milliseconds) — let's just leave that where it is for the time being. Click on the Next button again.

The second page of the wizard allows you to set the number of channels for this sequence; the default value is 16. Change that value to eight and then click Next. The third panel will allow you to rename the channels you just created. Skip past this panel by clicking Next again; I'm going to show you an easier way to edit the channel names.

Wizard panel number four will allow you to import music into the sequence; again, I'll show you how to do this later, so just click on Next. Now you can enter the sequence length. Since you're just at the learning stage, enter something short, say 0:30 (30 seconds). The final panel allows you to set up hardware plugins. You don't need to do this right now, so click on Create It and you'll be presented with a dialog to name the sequence. Enter something like Training Sequence in the text field and then click OK. Vixen will create an empty sequence and



■ FIGURE 4. Start Install.



■ FIGURE 5. Empty Sequence.

present it in a row-column format as shown in Figure 5. Each row is an output channel; each column is an event period. Each cell in the table holds a value for the channel at that time that is expressed from 0% to 100%. Move your mouse around in the field of cells. You should see little block markers to the left of the channels and just above the column time-line.

These markers assist in finding a specific row/column (channel/time) cell when sequences are long and this display is set to view a lot of cells (you'll find row and column magnification levels on the sequence toolbar).

Note that the rows are given very bland names: Channel 1, Channel 2, etc. You can change any of these

names by right-clicking, and then selecting Change Channel Name from the context menu. To me, this process is okay for a small number of channels, but I find importing a list of names from a text file to be easier. Here's how I do it: From the Sequence menu in the main window, select Export channel names list. Vixen will export a text file containing the current channel names to its Imports and Exports folder.

Using Windows Explorer, navigate to this folder and you should find a file called Training Sequence_channels.txt. Open this file with your favorite text editor, change the names, and then save the updated file. As you can see in Figure 6, I changed the names to match Santa's reindeer. Now go back into Vixen and select Import channel names list from the Sequence menu. From the dialog, select the file you just edited and click Open. Two things are going to happen: 1) Vixen will count the number of lines in the file you selected and set the channel count to that and, 2) Each line in the file will be used to rename the channels.

You can see that the import

process can actually be used to modify the number of channels, as well as rename them in one fell swoop; I find this quite handy.

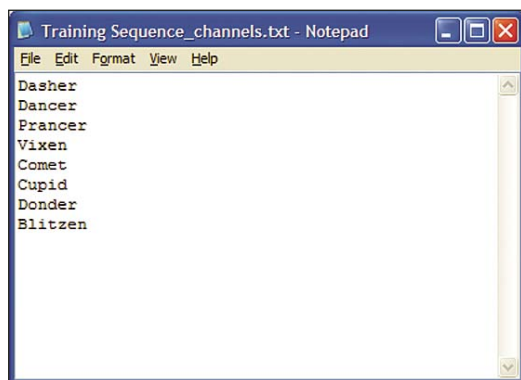
Okay, let's do some sequence editing. Just as you have to select a cell in a spreadsheet to change it, the same applies to Vixen. You can select a single cell by clicking on it, or a group of cells by doing a click-and-drag with the left mouse button — and, of course, you can select cells from multiple rows and columns. As with other Windows programs, you can select one cell and then shift-click a second cell to create a range selection. Once a selection is made, the easiest edit is to toggle the cells on (100%) or off (0%) by pressing the space bar.

You can actually create a quick sequence by keeping one hand on the mouse and the other on your space bar, clicking and tapping as you go. Want to make a quick chaser? Hold down the Ctrl key and then click-and-drag with the left mouse button. You'll see a line drawn between the first cell and the cursor; when you release the mouse button, the cells that fall under the line will be set to 100% — boom, instant chase!

Let me show you another cool trick that will save time as you develop complex sequences. You can, of course, select, copy, and paste a group of cells within a sequence. If you come up with something especially intricate, you may want to drag-select a group of cells, then right-click and select Save as a Routine. Enter an appropriate name in the dialog and then click OK. Now click on another cell to select, right-click, and then select Load a Routine from the context menu.

Cha-ching, the group of cells that you saved earlier is loaded into your sequence at the selected cell — kind of like a rubber stamp. You can use that routine in this sequence or any other sequence; it's saved on your hard drive for whenever you need it.

So far, we've played with pure digital values (on and off), but as I stated at the beginning Vixen cells actually contain an analog level of 0% to



■ FIGURE 6. New Channel Names.

100%. On the lower toolbar in the sequence window, you'll find icons for the following editing functions:

- On
- Off
- Ramp On
- Ramp Off
- Partial Ramp On
- Partial Ramp Off
- Mirror Vertically
- Mirror Horizontally
- Invert

In addition, there are icons for three automated effects:

- Random
- Sparkle
- Shimmer

The editing and effects tools operate on all selected cells. The edit functions are probably obvious, though I'll note that Ramp On and Ramp Off require no input; the Partial Ramp On and Off functions allow you to enter start and ending values for the cells. And, of course, ramp features are applied on a row-by-row basis.

As with the basic editing tools, the Random effect is fairly obvious. Sparkle creates an effect not unlike a Fourth-of-July sparkler where the selected rows are lit brightly, then fade out over a random time — it's very nice. There are Frequency (number of changes) and Decay Time settings that let you tune the effect for the selected cells. Long decays look really nice. Shimmer creates more of a candlelight effect, and if you have multiple rows selected they will behave in the same manner based on the Frequency setting (there is no Decay Time with Shimmer).

If you want to simulate a bunch of candles with Shimmer, select each row (output channel) individually and give them a slightly different Frequency value.

One note about Shimmer: Make sure that you move the Frequency selection slider off the "zero" position; I've found that leaving it at this position occasionally causes Vixen to hang on my PC.

■ **FIGURE 7. Event Sequence Music.**

The best way to really learn Vixen's editing features well is to select a group of cells and press a tool button — you'll master editing sequences inside an hour. Here's the thing, though: Basic editing is simple, creating beautiful sequences will take time, so do put in some "play" time before you move forward with an actual lighting project.

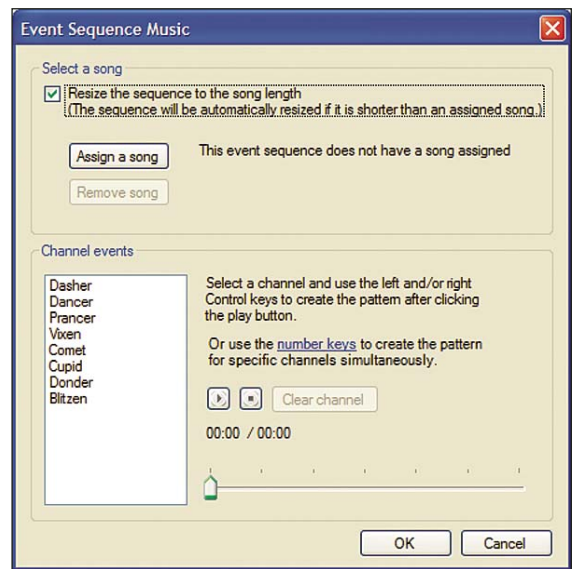
Facing the Music

While switching and fading a bunch of lights is really cool, it gets even better when those events are synchronized with music, and Vixen was designed with this in mind. On the top sequence menu, you'll find an icon that looks like a musical note. When you click this button, you'll get the Event Sequence Music dialog (Figure 7). Click on Assign a Song and navigate to the WAV or MP3 file of your choice. After selecting, Vixen will make a copy of your audio in its Music folder.

Click OK to close the dialog — the display window hasn't changed. On the middle toolbar, there is an icon that looks like an audio waveform (the Audio Visualizer). Click on this button to display your audio on the timeline above the channel events.

At this point, you may have a sequence created and even added audio, but are not able to play it. The reason is that Vixen requires an output driver to be installed for the sequence. In the beginning as you're learning, the best driver to use is one that doesn't require any hardware to be connected to your PC. From the middle sequence menu, select

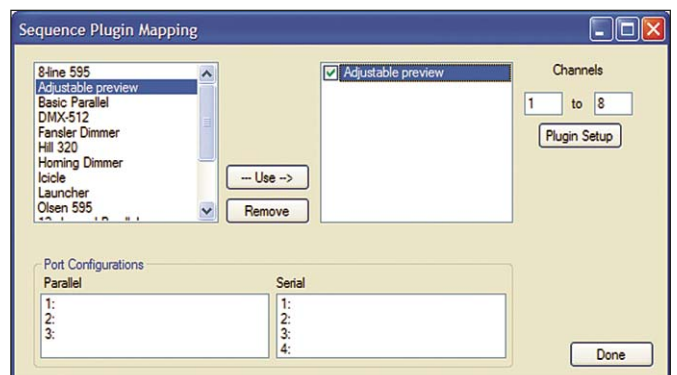
■ **FIGURE 8. Sequence Plugin Mapping.**

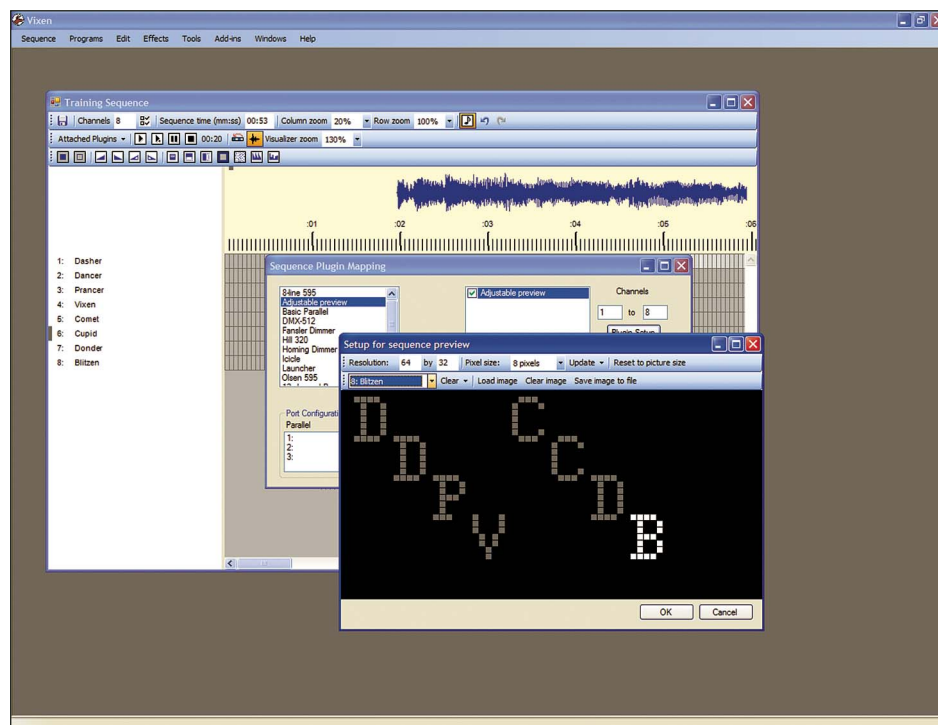


Attached Plugins to get the Sequence Plugin Mapping dialog (Figure 8).

On the left side of this dialog, you'll find a list of available plugins. Vixen's architecture allows you to drop new plugins (DLLs) into the Plugins folder, as required. K.C. routinely adds new hardware drivers and makes them available on Vixen's downloads page. Near the top of the available plugins list, you'll find one called Adjustable preview. Click on it, and then click the Use button to move it to the right-side list. Now enter the channels — 1 to 8 — for this plugin.

The plugin is selected, but not yet set up. Click on the plugin name in the right-side list and the Plugin Setup button will be enabled. Go ahead and click on it. What you'll get is a blank screen. The purpose of this plugin is to allow you to "paint" outputs on a canvas that will "light" when the sequence is played. In the future, you





■ FIGURE 9. Preview Plugin Setup.

can import background pictures, like your house or a Christmas tree, and even change channel colors that will be reflected on this screen. But for now, let's just keep things simple and stick with the black background.

Select one of your channels from the drop-down and then paint the lights onto the background; the left mouse button draws pixels, the right mouse button erases pixels. Figure 9 shows a simple example where I painted letters that match the first character of each reindeer's name onto the background. The cool thing about the preview panel is that it works with brightness levels, so

if you have variable levels in your sequence, you will see them in operation on this screen. Close the setup and mapping dialogs and then click on the Play Sequence button in the middle tool bar (you can also press F5). The preview window will open and your painted lights will respond to the sequence data you created, in sync with the music. Pretty neat, huh?

Driving Lights

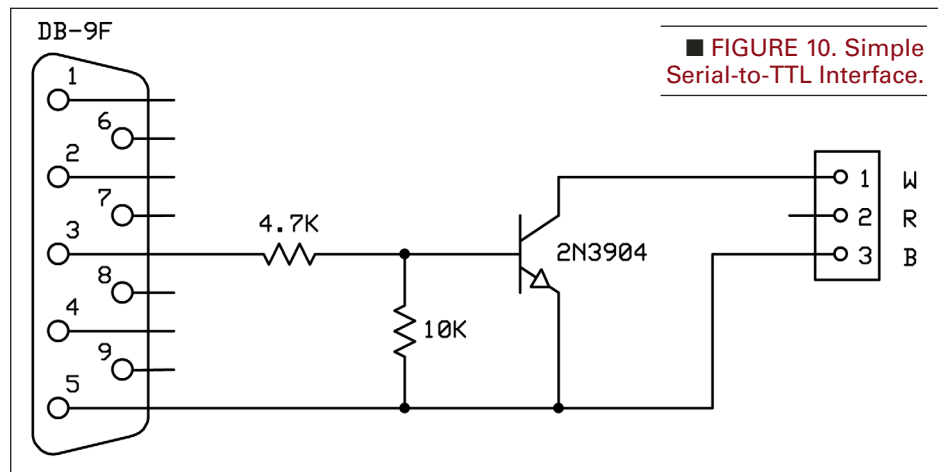
While creating and viewing sequences on screen is entertaining, the whole point of using Vixen is to

drive lights. In my opinion, this is another area where Vixen really rocks. You see, in addition to its you-can't-touch-that price tag, Vixen is laissez-faire when it comes to hardware; you get to decide what actually controls your lights — you're not forced to use any specific piece of hardware; you could even create your own!

Think of it this way: You can write a letter using Microsoft Word and print it on any printer that has a driver installed on your computer. Vixen works the same way: It will send sequence values to your specific driver and that driver is responsible for controlling the lights (with its hardware) to its own capabilities. Just as a dot-matrix printer will not have the same quality output as a laser printer, a pure digital output device will not allow the same sophistication of output as a device that supports lamp dimming. That doesn't mean you can't create fantastic devices with a simple switcher. It just means that you can't take advantage of all of Vixen's cool features.

While there are a lot of neat circuits that can be driven by Vixen on the Internet at places like www.computerchristmas.com, I happen to have a 120 VAC dimmer board that I helped design for EFX-TEK — the FC-4 — so I'm using that in my personal projects. The FC-4 has — surprise — four channels, but can be chained together for a total of 16 (each board has a two-bit address). Granted, this is not a lot of channels, but probably enough for a really cool indoor display, or perhaps a Christmas tree or an automated Hanukkah menorah.

K.C. was kind enough to create an FC-4 driver to my specifications. The driver provides for COM port and baud rate (2400 or 38.4K baud) selection, and is smart in that it knows that channels 1 through 4 will be sent to board address %00, channels 5 through 8 will be sent to board address %01, etc., up to a maximum of sixteen channels. The driver also knows that the FC-4 uses the Parallax AppMod protocol, so each message block is sent with the appropriate header, board address,



■ FIGURE 10. Simple Serial-to-TTL Interface.

command ("S" for set levels), and the four channel levels for the board.

Now, there's one bit of extra interface hardware required for the FC-4. You see, it was designed to be controlled by small micros like the BASIC Stamp so it uses TTL level serial, and that is not what is coming out a PC's serial port. The interface is easy: a couple connectors, a common transistor, and a couple resistors. Figure 10 shows the schematic for the serial-to-TTL interface. I use female-female extender cables (Parallax #805-00012) to daisy-chain the FC-4 modules. Even at the relatively tame baud rate of 38.4K and with a 10-byte message per board, it only takes about 10.4 milliseconds to update all 16 channels, so I can adjust Vixen's Event period length (in the Sequence >> Settings menu) to create really snappy changes in my output.

Beyond the Basics

Again, the toughest part of Vixen is going to be the creation of a sequence, especially one that is in perfect sync with a piece of music. Just as it's easy to pick up a pencil, creating great art with it is another story – the same holds true with Vixen, so be patient with yourself. I promise that the patience will pay off and once a great sequence is created, you can fold that into bigger projects using Vixen's programs and timers capabilities. The Programs menu allows you to tie sequences together. Beyond that, you can use the Timers function (also in the Programs menu) to start your sequences or programs at a specific time of day.

Oh, one last little Vixen tidbit: You may have looked for but not found the Save As... item in the Sequence menu.

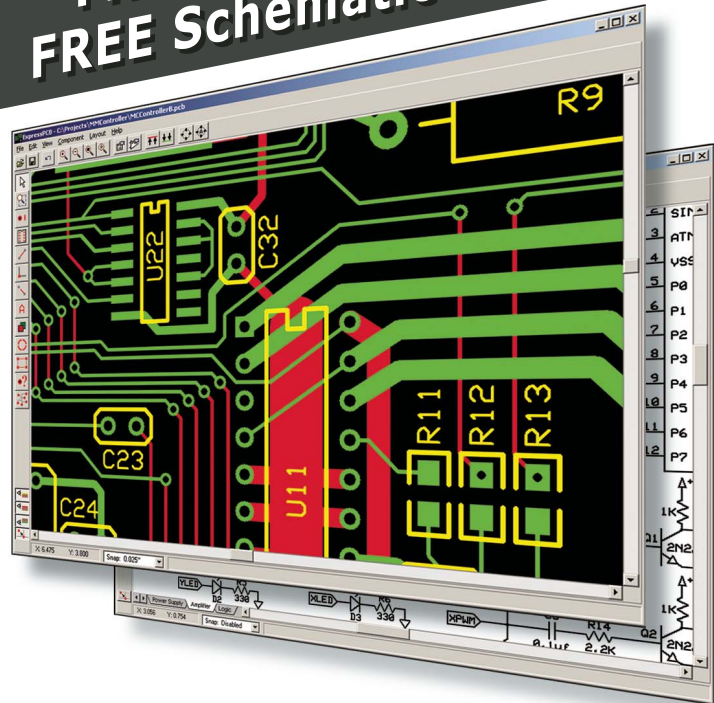
You won't. Vixen is unique – in more ways than one – and in many places, you can make changes right in the menu – this is one of those places. To perform a "save as" function, you will open the Sequence menu and then click on the sequence name to get an edit box. Change the name and then press Enter – you've just done a "save as." This same strategy is used in other menus, so look for it.

Light It Up

Okay, it's time to stop reading and time to start creating cool lighting sequences. Grab a cup of Joe or hot chocolate, get your sequences programmed, and then get ready to bask in the glory of your neighbor's adoration!

Happy holidays, and may the season bring you and yours all the peace and joy the world has to offer. **NV**

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Creating authentic
looking models is
a passion of mine.

To enhance my
model railroad
setup, a realistic
(but inexpensive!)
crossing signal was
just the ticket.

BUILD A MODEL RAILROAD CROSSING SIGNAL

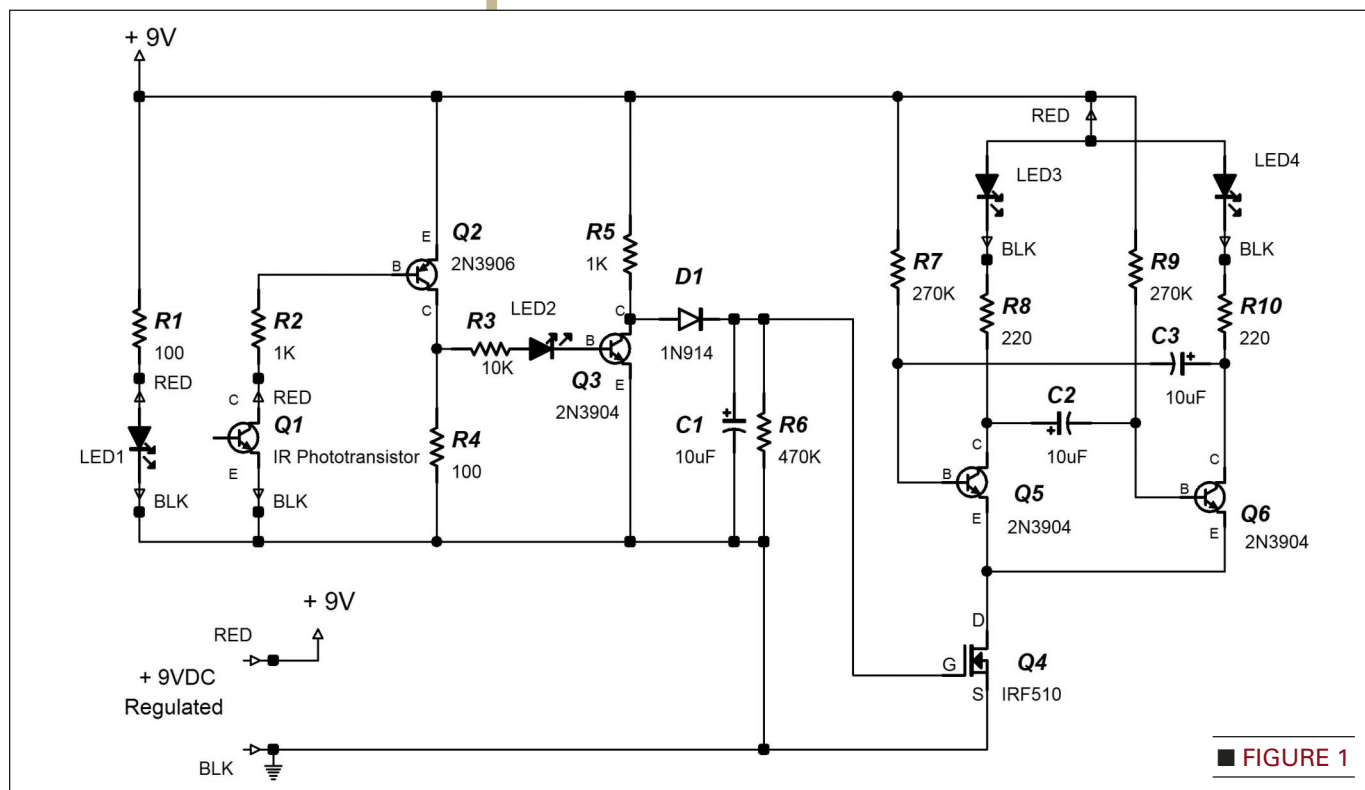
The circuit in Figure 1 is the schematic for my model railroad crossing signal. The completed printed circuit board (PCB) is shown in Photo 1a and Photo 1b. The circuit uses an infrared emitter and detector to determine the presence of the model train. When the infrared beam is broken, the two red crossing signal LEDs flash alternately.

Theory of Operation

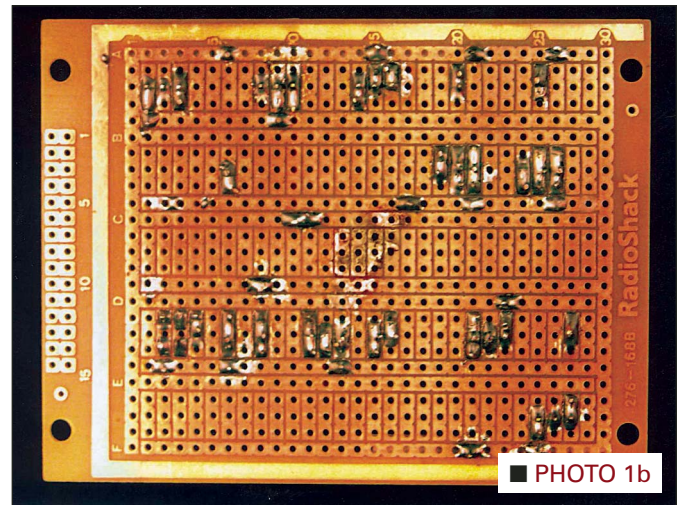
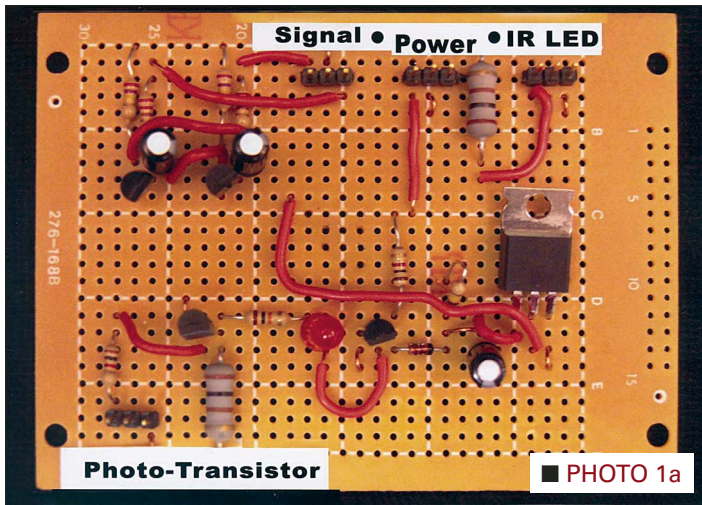
The infrared LED (emitter) is on

one side of the track while the IR phototransistor (detector) is on the opposite side of the track. These components are mounted in a line-of-sight fashion so that the infrared light from the LED shines on the phototransistor. The phototransistor is shielded from stray light by aluminum tubing (refer to Figure 2).

The infrared emitter and detector PCB connections are shown in Figure 3. Brackets (see Figure 5) are mounted to emitter and detector boards with 4-40 screws and nuts.



■ FIGURE 1



The PCBs are then secured to the model railroad base on either side of the track with #4 self-tapping screws.

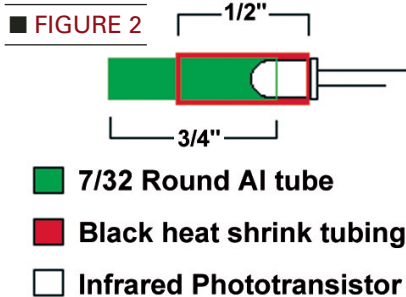
When in the off state (no train to block the IR beam), Q1 pulls the base of Q2 low. This causes the voltage at the collector of Q2 to be approximately 8.5V. This is greater than 2.7V (the forward voltage of LED2 +Vibe of Q3). As a result, Q3 is on. Q3's collector is near zero volts, keeping Q4 turned off. When Q4 is off, the ground of the bistable multivibrator (an oscillator formed by Q5 and Q6) is not connected to power ground. This disables the crossing signal.

On the other hand, when the IR beam is broken, Q2 is off and R4 pulls the collector of Q2 to near ground. This voltage is less than 2.7V and turns off Q3. R5 then raises the collector of Q3 to 9V. As a result, D1 is forward biased and charges C1. Q4 then conducts and connects the oscillator ground to power ground. This causes LED3 and LED4 to flash in an alternate fashion.

Due to the action of C1 and R6, the IR beam must remain broken for at least five seconds before the oscillator is turned off. If R6 is reduced, the delay time is also reduced.

Construction

As mentioned earlier, the IR emitter, detector, and signal PCBs are made from stripboard (see Figure 3 and Figure 4). Note the polarity of the LEDs and



phototransistor when constructing these boards. To verify the operation of the circuit, the emitter and detector PCBs are temporarily mounted 3" apart on a block of wood using two of the brackets shown in Figure 5 (also refer to Photo 2). A RadioShack 276-168 Universal Component PCB is used when constructing the remainder of the circuit.

Note the "X" on Figure 1b. This denotes a cut trace. When mounting the capacitors, be sure to observe the correct polarity.

The negative lead of the capacitor is labeled on the part. The other lead corresponds to the positive lead. This is the lead marked on the schematic. The bar on the LED2 shown on the schematic corresponds to the lead closest to the

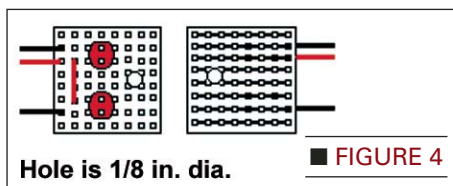


FIGURE 3 Infrared LED Transmitter LED

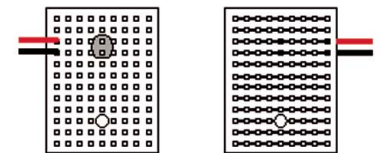
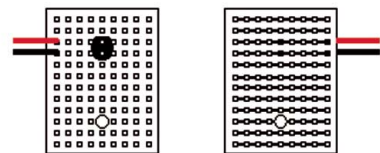


FIGURE 3 Shielded Phototransistor Receiver PCB



Holes in PCBs are 1/8 in. dia.

flat side of the LED package. For D1, the bar on the schematic represents the lead closest to the black band on the part. When mounting the transistors, reference Figure 6 for pin designations.

The wires from the emitter, detector, and signal PCBs can be soldered directly to the main circuit board. The wire colors are marked on the schematic.

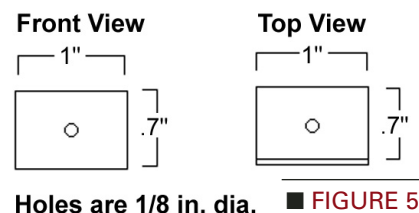
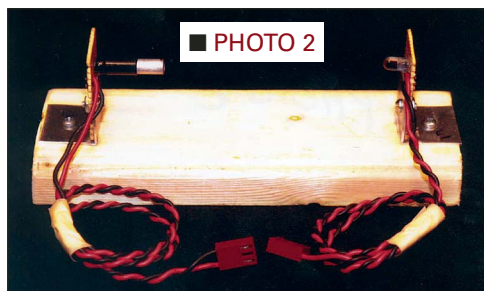


FIGURE 5 Holes are 1/8 in. dia.



■ PHOTO 2

ic. When wiring the signal board to the main circuit board, the two black wires are interchangeable. Instead of soldering these wires, they can be attached with .1" female crimp housing connectors mated with .1" headers soldered to the PCB. Another connector can be used for input power to the main circuit board.

Use

The emitter and detector should be mounted before the crossing signal for realistic operation. The emitter and detector assemblies can be camouflaged with some synthetic foliage or rocks. Just be sure there is an optically clear path between the two assemblies.

Remember if the IR path is unbroken for less than five seconds, the crossing signal will continue to flash. The circuit draws approximately 200 mA at 9V. You may wish to connect a 9V power supply of your own design to run the circuit. However, a much simpler solution is to use a 9VDC regulated wall adapter, such as a Jameco part number 190529CM.

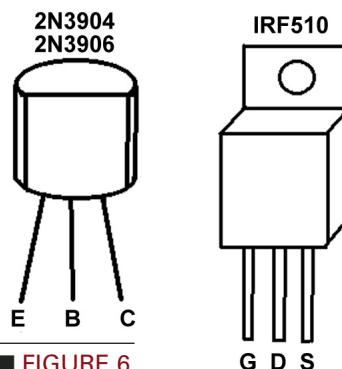
Have fun building and operating this model railroad crossing signal. **NV**

PARTS LIST

Item	Part Value	Part No./Supplier
□ R1,R4	100Ω 1W resistor	594-5073NW100R0J
□ R2,R5	1K 1/4W resistor	30BJ250-1.0K
□ R3	10K 1/4W resistor	30BJ250-10K
□ R6	470K 1/4W resistor	30BJ250-470K
□ R7,R9	270K 1/4W resistor	30BJ250-270K
□ R8,R10	220Ω 1/4W resistor	30BJ250-220
□ C1-C3	10 μF 50V capacitor	647UVR1H100MDD
□ Q1,LED1	IR phototransistor & LED	276-142/RadioShack
□ Q2	2N3906	511-2N3906
□ Q3,Q5,Q6	2N3904	511-2N3904
□ Q4	IRF510	512-IRF510A
□ D1	1N914	610-1N914
□ LED1-LED4	Red LEDs	696-LXS093SRD/D
□ Perfboard		276-168/RadioShack
□ Stripboard		ECS-4/All Electronics
□ Aluminum Sheet	K & S Metals	Hobby shop
□ (2) 4-40 Screws		Various
□ (2) 4-40 Nuts		Various
□ 7/32" Aluminum tube	K & S Metals	Hobby shop
□ Power supply	9 VDC regulated	90529CM/Jameco
□ Hookup wire		Various
□ Panhead screws	#4 x 3/8" self-tapping	Various

NOTE: Supplier is Mouser unless otherwise noted (www.mouser.com). Links to other suppliers: Jameco — www.jameco.com; All Electronics — www.all-electronics.com; RadioShack — www.radioshack.com

Transistor Pinouts



■ FIGURE 6

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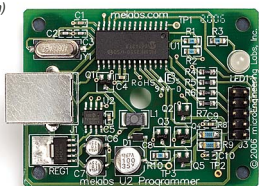
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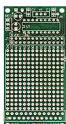
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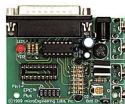
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H D T V

Buyer's Guide

So, after reading my last article on the end of analog broadcasting, you've decided to purchase a new Digital TV. A look around the electronics superstores, as well as smaller boutique, high-end AV stores reveals a multitude of choices. Many factors will go into your choice for a new TV: screen size, room lighting, cosmetic appeal and, of course, price. But be aware that many of the features and specifications that you will see listed in a showroom can be deceiving.

by Jeff Mazur

For example, your new DTV will absolutely include an ATSC tuner since this is now mandated by law (unless you specifically buy a unit designated as a video monitor). While some low-end devices still use 4:3 aspect ratio CRT displays, most likely your new set will have a 16:9 aspect ratio, fixed-pixel display such as LCD, plasma, etc. So it's tempting to assume that all such TVs are HD. But you'll have to look carefully at the specs to see exactly what you are getting and how it will fit into your home entertainment system.

We'll take a look at the various factors and technologies you need to know before heading out to make a purchase. Some of these factors will be based upon your personal taste and particular viewing environment. We'll try to give you the technical background and tools to pick the right TV for your taste and budget. We'll also take a look at the various ways to connect your TV to other components of your home entertainment system.

Location, Location, Location

A good place to start is to examine the location where you will be placing your new TV. In most cases, you will be replacing an older (perhaps CRT-based) set, which probably has a 4:3 ratio screen. If the set needs to fit within a certain space (e.g., in a pre-existing entertainment center), then carefully measure the space; include the depth measurement although this should not be an issue since most new sets are much shallower than older units.

After choosing the location, you will now be ready to determine what size and perhaps type of TVs you should consider. For most situations, the optimum picture size is determined by how far away it will be viewed. For years, the standard rule for optimum viewing distance was around four times the picture height, or 2.4 times the screen size (measured diagonally).

That is, for a 32" TV with a vertical screen height of 19.2", you should sit at least 76.8" or 6.4 feet away for proper viewing. Any closer,

and the average person (with 20/20 vision) would start to see the individual scan lines of the TV picture. Go further away, and you start to lose resolution as your eyes can no longer discern fine details.

With HDTV, several factors have changed. First, there are more scan lines and thus they are more closely spaced for the same size screen. Then we have the 16:9 aspect ratio which changes the diagonal-to-vertical height calculations. For the true movie theater experience, you also need to be close enough so that the horizontal viewing angle of the screen is at least 30 degrees (per SMPTE standard EG-18-1994).

For widescreen TVs, four times picture height now translates to a viewing distance of approximately two

Note

Figures 2, 3, 4, 10, 11, 12, and 13 are courtesy of Wikipedia, the free encyclopedia (licensed to the public under the GNU Free Documentation License).

Table 1

Screen Size	Viewing Distance
30"	3.75-6.25 feet
34"	4.25-7 feet
42"	5.25-8.75 feet
50"	6.25-10.5 feet
56"	7-11.75 feet
62"	7.75-13 feet
70"	8.75-14.75 feet

times screen size. Although the higher resolution of HDTV would imply that you could move closer before seeing its line structure, chances are you will still be watching quite a lot of standard definition programs. And there are other reasons why not to get too close (more on that in a moment). Therefore, a good rule of thumb would be to sit between 1-1/2 and 2-1/2 times the screen size as shown in Table 1.

These numbers should be satisfactory for most people, although there is still some debate about the exact parameters. For example, one could argue that technically you can get closer to a TV showing 1080p material than one set for 720p display. However, this assumes that the limiting factor is the line and/or pixel pitch; i.e., the distance at which you start to see the discrete structure of an image.

As we discussed last time though, TV broadcasts (and to a similar degree DVD pictures) are highly compressed (roughly 100:1). Therefore, you will start to notice compression artifacts

FIGURE 1. The three primary colors (red, green, and blue) mix together to form the secondary colors (yellow, cyan, and magenta), as well as all other colors including white.

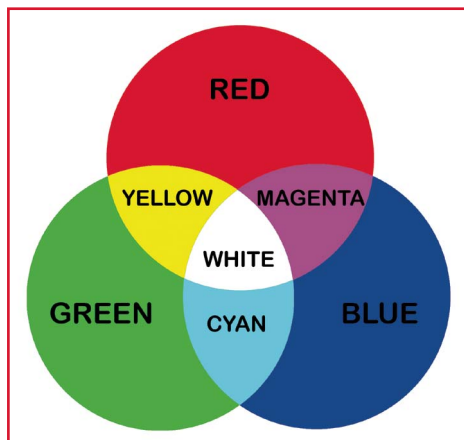


TABLE 1. Optimum viewing distance for a given screen size.

long before you get close enough to see the image's line structure.

Screen technology and surface material — along with lighting and screen reflections — will also affect the results. Your own visual acuity, display resolution, and even program material will vary. Use Table 1 as a guide,

but the exact size TV you get may also be based on what fits into your existing furniture or décor.

After choosing the size for your new HDTV, you can now narrow down what types of screens are available in that size. Smaller screens will most likely be LCD or plasma. Larger home theaters may require a rear or front screen projection system. Let's take a closer look at the various technologies used today so that you'll understand the pros and cons of each.

Common Characteristics

All color TVs rely on some form of tri-stimulus display. This means that they create a color image by breaking it up into three separate monochrome pictures — one each for the red, green, and blue parts of the image. These different images are then displayed together, with the colored pixels very close together (or rapidly in sequence in the case of DLP sets). The eye then merges these colors together to create a single color based upon the mixture of red, green, and blue.

For example, if both the red and green pixels are displayed at full brightness, the eye will perceive a

single yellow pixel. In case you don't remember the additive properties of the primary light colors, take a look at Figure 1.

All TVs can be categorized as either direct view or projection (front or rear). Direct view sets use a CRT, plasma, or LCD display. Front projection sets throw an image from within the viewing area onto a reflective screen (like a movie theater) while rear projection sets are usually self-contained and present the image on the back of a translucent screen through which the picture is viewed. The latter have become most popular for medium to large home theater installations. At one time, projection sets used CRTs, but they all now use LCD, LCOS, or DLP imagers. Let's examine how each of these technologies works.

Cathode Ray Tube

We'll mention the venerable CRT only in passing, as few sets are still available with these bulky, heavy glass tubes. As you probably know, the CRT creates a TV image by scanning the back of a phosphor-coated screen with three separate electron beams. When an electron strikes the phosphor, it momentarily glows with a color determined by its chemical composition. Three different phosphors are used to create red, green, and blue light (see Figure 2). The number of electrons striking a given spot on the screen is varied by controlling the beam current; this, in turn, determines the brightness and color for each spot as the beam scans left to right and up and down the screen.

The result is that a complete color image is

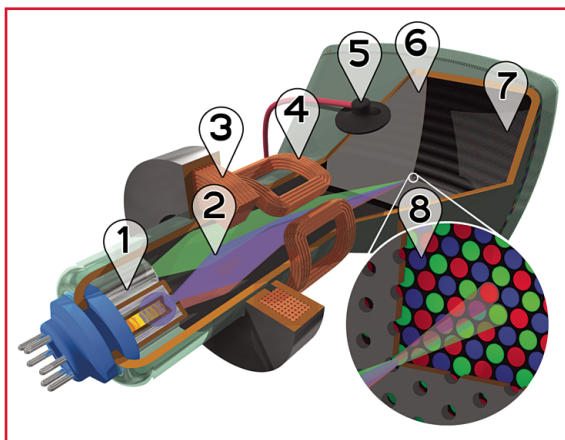


FIGURE 2. Basic elements of a CRT TV display: 1) Electron guns; 2) Focusing coils; 3) Deflection coils; 4) Anode (high voltage) connection; 5) Mask for separating beams for red, green, and blue part of displayed image; 6) Phosphor layer with red, green, and blue zones; and 7) Close-up of the phosphor-coated inner side of the screen.

“painted” on the screen in 1/60th of a second for standard NTSC. As the light from each phosphor begins to fade out, a new image is displayed by the next field’s scanning. This, plus the persistence of vision provided by the human visual system, causes us to see a smooth, moving image on the TV display.

CRT pros are excellent color rendition, deep blacks, wide viewing angle, and few processing artifacts. The cons are excessive size, weight, heat, and cost for larger displays. CRTs are also prone to image burn-in when a static image is left on the display for long periods of time.

Plasma

A Plasma Display Panel (PDP) creates an image by illuminating tiny cells of gas (see Figure 3). When a high voltage is impressed across the cell, the gas inside becomes ionized creating lots of free electrons (a plasma). These electrons then strike a phosphor coating in the cell causing it to emit light, much like a CRT.

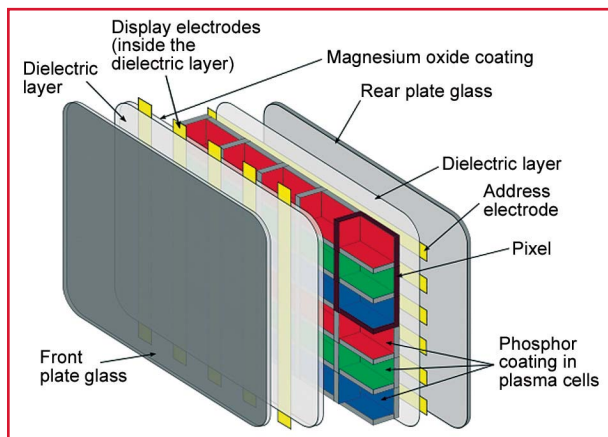
Plasma pros include excellent color rendition, deep blacks, and wide viewing angle. They are also very thin and thus easy to hang on a wall. The cons are moderate weight and heat generation, and high cost (although they’re dropping). It is also very difficult (i.e., expensive) to create cells small enough for a 1080p display. Plasmas are also prone to image burn (although again, they’re getting much better).

LCD

Liquid Crystal Displays operate by placing colored filters and LCD elements in front of a uniform backlight (usually fluorescent, see Figure 4). The actual LCD element is formed by sandwiching a specific crystal compound between two linear polarizers. Light passes through the first polarizer, then through the crystal molecules, and finally reaches the second polarizer, which is oriented perpendicular to the first one.

Due to the nature of the twisted nematic liquid crystal material, the polarization of light passing through it

FIGURE 3. A Plasma display panel is constructed in several layers. When a voltage is impressed across the display and address electrodes, the gas between them is ionized causing the phosphor inside to glow.



is rotated 90 degrees and thus normally passes freely through the second polarizer, creating a bright spot. However, when a voltage is applied across the crystal, the structure of the molecules changes. In essence, the normally helical alignment is pulled straight and thus no longer causes a change in polarization. Therefore, the light is now blocked by the second polarizer and appears as a dark spot. The color filter pattern on the next layer determines whether this represents either the red, green, or blue portion of a given pixel.

LCD Projection

LCD projectors use a very bright light source, which is split into red, green, and blue paths. Each colored light path passes through an LCD device where the separate images are created. The light from each of the three LCDs is then combined and projected onto a screen for viewing.

LCD pros include low cost, very small and light, and low susceptibility to burn-in. The cons are lower contrast and less deep blacks, and smaller viewing angles, especially for projection units.

structure directly over a static RAM memory cell. When a “1” is written to the memory cell, the electrostatic charge causes the mirror above to rotate slightly. This rotation is enough to change whether the light for each pixel is projected out to the display or reflected internally.

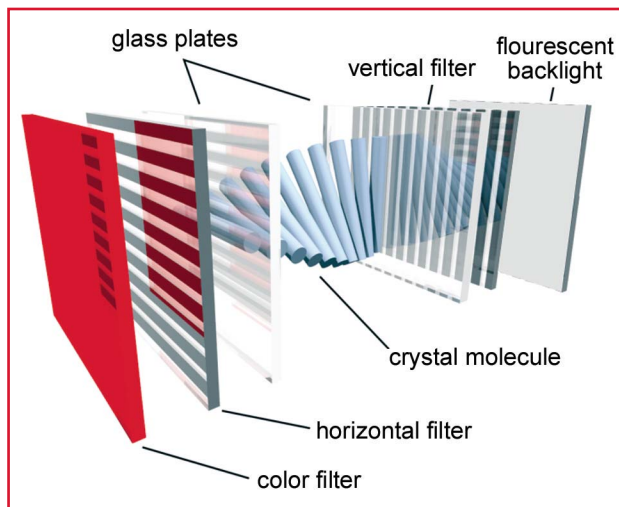
Consumer DLP sets use only one DMD device. To create color images, the light is first passed through a spinning color wheel. The DMD then rapidly alternates between displaying the red, green, and blue signals (see Figure 5).

DLP pros include low cost, very small and light, and no burn-in (although it is possible for one mirror on the DMD to get stuck and stop working; if a given pixel gets stuck in the ON position, this creates a super bright pinpoint of light at that location on the screen which is VERY distracting and would probably require replacement of the entire DLP engine. The cons are extra complexity,

DLP

Digital Light Processing technology is based upon the Digital Micromirror Device (DMD), a tiny semiconductor chip which contains up to two million microscopic mirrors. Each mirror is mounted on a hinge

FIGURE 4. Details of a Liquid Crystal Display element.



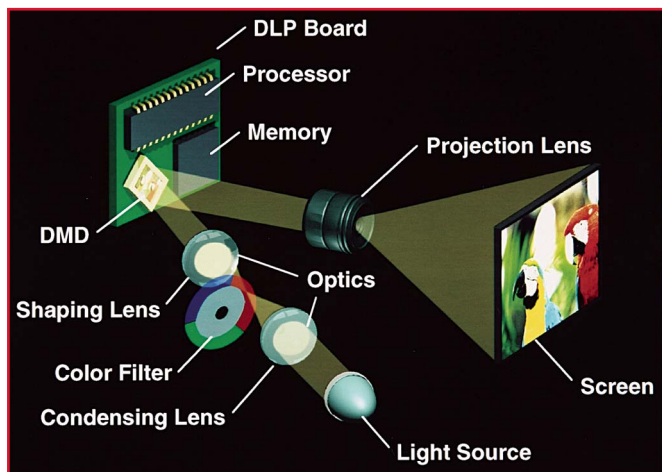


FIGURE 5. Main components of a DLP TV.

light through it.

LCOS sets can create vivid pictures with high contrast ratios, few distortions, and no burn-in. They are somewhat higher priced and, being projection units, suffer the same viewing axis issues.

possible “rainbow effects” from the spinning color wheel, and smaller viewing angles since these are always projection units.

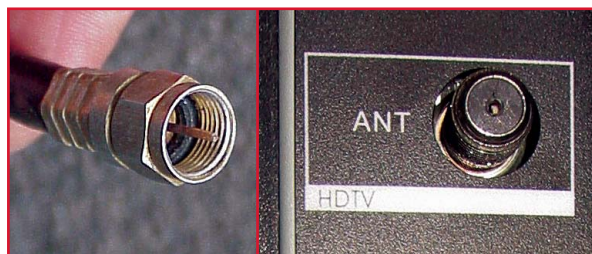
LCOS

Liquid Crystal on Silicon displays are also known as D-ILA (JVC’s Digital Direct Drive Image Light Amplifier) and SXRD (Sony’s Silicon X-tal (Crystal) Reflective Display). Basically, this technology combines the best features of both LCD and DLP. It uses LCD structures but causes light to reflect off of the LCD rather than pass

Other Technologies

On the drawing boards are displays made of Light Emitting Diodes (LEDs), Organic LEDs (OLEDs), Surface-conduction Electron-emitter Devices (SED; sort of like a one inch thick CRT), and even more exotic technologies. Many of these promise larger, brighter, thinner, and less power hungry TVs of the future. Various attempts at 3D TV are also in development. Most use some form of anaglyphic display with special viewing glasses. Perhaps someday there may even be a holographic display, which could provide true 3D viewing, as well.

FIGURE 6. RF (F-connector) input.



Connections

Most TVs today (especially large screens) offer a dazzling array of connections to hook up to your other home entertainment equipment. While it is possible to get away with a single RF coax feed (Figure 6) from an antenna or set-top box, most likely you will take advantage of the higher quality interfaces available. Not that an RF connection doesn’t have some advantages: it consists of a single wire carrying all channels at once, enabling all functions of the TV and its

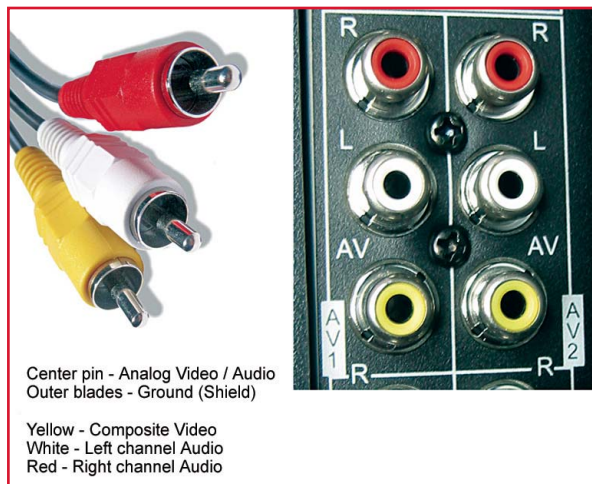


FIGURE 7. Typical composite video with stereo audio connections.

remote control such as Picture-In-Picture (PIP), and is easy to split to feed multiple devices.

An antenna feed will receive all local channels (analog and digital of course, including HD). But satellite and cable feeds, including premium and pay-per-view options, will most likely require a Set-Top Box (STB). And while you may be able to connect this box to your TV via an RF connection (usually on Channel 3 or 4), this will not give as clear a picture or sound as one of the other following connections.

These alternatives, however, will only present a single channel as tuned or selected by the STB (notwithstanding the STB’s capability to present its own PIP). The improved signal quality is accomplished by feeding separate video and audio signals directly to the TV (bypassing its own built-in tuner). In this case, the TV will be set to display one of its external video inputs. The exact nature of the external video will depend upon the connection type used.

Composite Video (Single RCA Jack)

The most common connection for video equipment is the composite (or NTSC/PAL) connection which is usually provided as an RCA jack. It will likely have a yellow color inside and be associated with stereo audio jacks which are usually white and red (see Figure 7). Composite video carries both luminance (brightness information) and chrominance (color info), as well as sync (synchronization signals) combined as a single signal over a shielded coaxial cable. This is an improvement over the RF modulated signal carried by an RF cable, but suffers many of the same distortions due to the encoding and bandwidth limiting of the color info on top of the luminance video.

S-Video

Separate (S or sometimes, Y/C) video connections use a four-pin mini DIN connector to carry video as separate luma and chroma signals over two

coaxial cables (see Figure 8). By keeping these signals separate, many video artifacts (defects) can be avoided such as color dot crawl, color moiré patterns (e.g., on a striped or herringbone suit), and other cross color defects. The chroma signal, however, is still a bandwidth limited, quadrature modulated combination of both the I and Q color signals so it is only suitable for standard def (SD) signals. S-Video connections will also be accompanied by a set of analog audio jacks.

Component Video

Component video connections carry the original RGB (red, green, and blue) signals as three separate monochrome video signals (see Figure 9). This allows full bandwidth (high resolution) video to be transferred from one device to another. While some devices actually accept true RGB component signals, most equipment these days use YPbPr signals. These three signals are derived from the gamma corrected R'G'B' signals via the mathematical relationship shown in Table 2.

By sending the RGB signals through a matrix to derive the YPbPr signals, we again put all of the luminance information on one signal (Y) and use the remaining two to carry the color information. The Pb signal essentially represents the B-Y (blue minus luminance); Pr represents R-Y (red minus luminance).

This system offers many advantages over a simple RGB interface. For example, the single Y component can be fed into a black-and-white monitor to give a monochrome display. Some equipment may label these jacks YCrCb; this is technically incorrect as Cr and Cb refer to digital representations of the PrPb signals. Component connections may be accompanied by either analog audio jacks or possibly some form of digital audio connections.

DVI/HDMI

The Digital Visual Interface

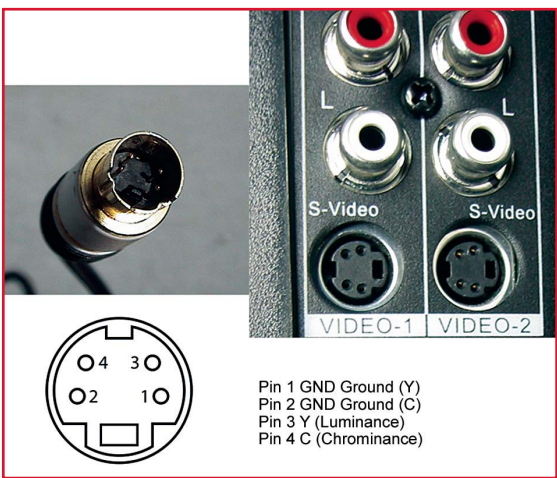
FIGURE 8. The S-Video connector carries separate Y and C signals.

(DVI) standard was developed as a way for carrying digital pixel data between devices. As such, it is a much better way to drive fixed-pixel displays such as LCD, DLP, and Plasma units.

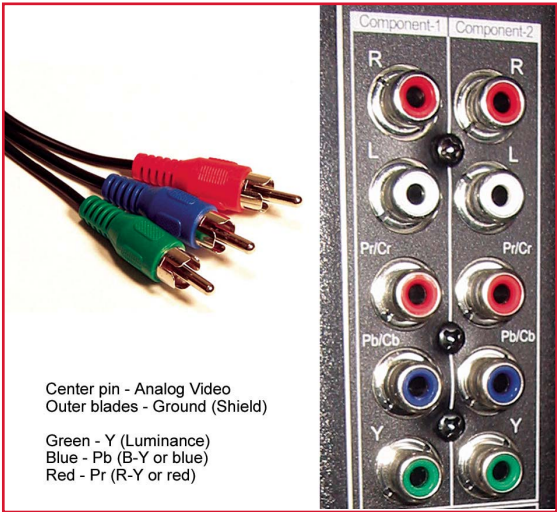
The DVI interface has several variations: single or dual link, analog and/or digital (see Figures 10a and 10b). Because of the various configurations, not all DVI plugs and jacks are compatible. For example, a DVI-A plug will not fit into a DVI-D socket because the holes for the analog pins will not be present. TVs that have a DVI input will usually use a single link DVI-D connector.

DVI supports a form of copy protection known as High-bandwidth Digital Content Protection (HDCP). This is designed to prevent people from making pristine digital dubs of copy protected material such as motion picture DVDs. Unfortunately, this can cause problems (covered next).

The High-Definition Multimedia Interface (HDMI) shown in Figure 11 is a further improvement on (and somewhat compatible with) the digital DVI standard. It adds multichannel digital audio and also supports the HDCP form of Digital Rights Management (DRM), as well as other control features. Once again however, the use of HDCP sometimes makes this less of an ideal interface between home theater components. This is because



Pin 1 GND Ground (Y)
Pin 2 GND Ground (C)
Pin 3 Y (Luminance)
Pin 4 C (Chrominance)



Center pin - Analog Video
Outer blades - Ground (Shield)

Green - Y (Luminance)
Blue - Pb (B-Y or blue)
Red - Pr (R-Y or red)

FIGURE 9. Component cables use separate connections for the red, green, and blue signals. Most sets use a modified set of signals known as YPbPr which are easily derived and converted back to the RGB signals (see text).



FIGURE 10a. Variations of the DVI connector.

Table 2

3YPbPr (ITU-R BT.601)	
Y =	$0.299 \times R' + 0.587 \times G' + 0.114 \times B'$
Pb =	$-0.168736 \times R' - 0.331264 \times G' + 0.5 \times B'$
Pr =	$0.5 \times R' - 0.418688 \times G' - 0.081312 \times B'$

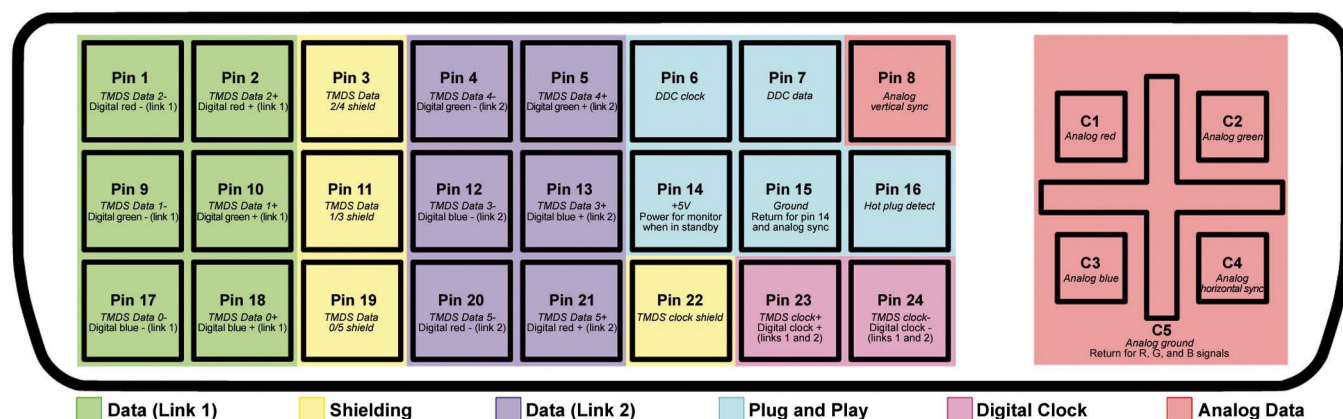


FIGURE 10b.
Pin descriptions.

- Pin 1 TMDS Data 2- Digital red - (Link 1)
- Pin 2 TMDS Data 2+ Digital red + (Link 1)
- Pin 3 TMDS Data 2/4 shield
- Pin 4 TMDS Data 4- Digital green - (Link 2)
- Pin 5 TMDS Data 4+ Digital green + (Link 2)
- Pin 6 DDC clock
- Pin 7 DDC data
- Pin 8 Analog vertical sync
- Pin 9 TMDS Data 1- Digital green - (Link 1)
- Pin 10 TMDS Data 1+ Digital green + (Link 1)
- Pin 11 TMDS Data 1/3 shield
- Pin 12 TMDS Data 3- Digital blue - (Link 2)
- Pin 13 TMDS Data 3+ Digital blue + (Link 2)
- Pin 14 +5V Power for monitor when in standby
- Pin 15 Ground Return for pin 14 and analog sync
- Pin 16 Hot plug detect
- Pin 17 TMDS data 0- Digital blue - (Link 1) and digital sync
- Pin 18 TMDS data 0+ Digital blue + (Link 1) and digital sync
- Pin 19 TMDS data 0/5 shield
- Pin 20 TMDS data 5- Digital red - (Link 2)
- Pin 21 TMDS data 5+ Digital red + (Link 2)
- Pin 22 TMDS clock shield
- Pin 23 TMDS clock+ Digital clock + (Links 1 and 2)
- Pin 24 TMDS clock- Digital clock - (Links 1 and 2)
- C1 Analog red
- C2 Analog green
- C3 Analog blue
- C4 Analog horizontal sync
- C5 Analog ground Return for R, G, and B signals

lution and let it do the scan conversions. Because DVI and HDMI are mostly compatible, you can connect a device with a DVI connection to one with HDMI. You can either purchase a special cable with one connection on each end (make sure you get the correct genders) or use an adapter to convert between the two.

VGA

If you want to connect your computer to your new TV, you will probably use either a DVI or VGA connection. For many years, the most common interface for computer monitors was the Video Graphics Array (VGA) cable. This 15-pin high-density “D” connection carries separate analog RGB signals along with H and V sync (see Figure 12). Two pins are used to carry Display Data Channel (DDC, a.k.a. VESA DDC) information that allows a monitor to communicate its capabilities to a graphics adapter inside the computer.

Firewire

Apple’s Firewire interface (a.k.a. IEEE 1394 or Sony’s i.LINK) can be found on many computers and other video devices like camcorders and STBs (see Figure 13). This interface is most often used to connect computer peripherals such as disk drives. But it is also sometimes used to carry digital video plus audio between devices. Although most TVs do not have a direct Firewire connection, other high-end devices in your home entertainment system may use them.

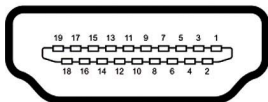
there is constant communication going on between devices connected via HDMI. If one device turns off, or if you try to change sources using an

HDMI switch, it often results in a complete shutdown of the interface. Despite being a standard (currently at version 1.3), there are still incompatibilities between various devices.

Also, you may be tempted to connect your TV to a set-top box using HDMI and let the STB pass the native video resolution on to the display. This seems like a good idea, but having the display reconfigure every time you change channels does not make for a pleasant viewing experience. In such a case, it would be better to restrict the STB to a single reso-

For Further Info

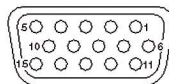
- Movie showing how DMD and DLP technologies work:
www.dlp.com/includes/demo_flash.aspx
- Interactive guide to connecting home entertainment equipment
www.ceaconnectionsguide.com/



- Pin 1 TMDS Data2+
- Pin 2 TMDS Data2 Shield
- Pin 3 TMDS Data2-
- Pin 4 TMDS Data1+
- Pin 5 TMDS Data1 Shield
- Pin 6 TMDS Data1-
- Pin 7 TMDS Data0+
- Pin 8 TMDS Data0 Shield
- Pin 9 TMDS Data0-
- Pin 10 TMDS Clock+
- Pin 11 TMDS Clock Shield
- Pin 12 TMDS Clock-
- Pin 13 CEC
- Pin 14 Reserved (N.C. on device)
- Pin 15 SCL
- Pin 16 SDA
- Pin 17 DDC/CEC Ground
- Pin 18 +5V Power
- Pin 19 Hot Plug Detect



FIGURE 11. HDMI can carry digital video and multichannel digital audio on a single connector.



- Pin 1 RED Red video
- Pin 2 GREEN Green video
- Pin 3 BLUE Blue video
- Pin 4 N/C Not connected
- Pin 5 GND Ground (HSync)
- Pin 6 RED RTN Red return
- Pin 7 GREEN RTN Green return
- Pin 8 BLUE RTN Blue return
- Pin 9 +5V +5V (DDC)
- Pin 10 GND Ground (VSync, DDC)
- Pin 11 N/C Not connected
- Pin 12 SDA I²C data (DDC)
- Pin 13 HSync Horizontal sync
- Pin 14 VSync Vertical sync
- Pin 15 SCL I²C clock (DDC)



FIGURE 12. The venerable VGA connector and pinout.

Wrapping It Up

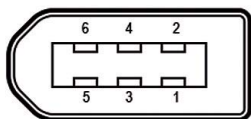
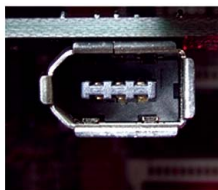
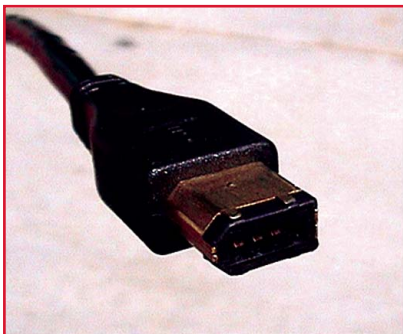
When considering how to hook up your new HDTV, make sure to check what the maximum resolution is for each input. For example, many TVs today tout 1080p capability; upon closer investigation however, you may find that this resolution is only available with component or HDMI connections.

And while we're on the subject of connections, don't fall for the hype around expensive cables. You know, the one's with oxygen-free copper, litz wire, or shielded AC power cords. I've seen HDMI cables selling for more than \$150; a quick search online can net you a good quality cable for less than \$10.

We'll continue our discussion next time with a look at

the audio side of HDTV, including analog, digital, optical, and surround sound. We'll also unravel issues that can cause audio-video delay (i.e., lip sync) problems. **NV**

FIGURE 13. Firewire (a.k.a., IEEE 1394 or iLink) six-pin connector.



- Pin 1 - Power
- Pin 2 - Ground
- Pin 3 - Twisted-pair B-
- Pin 4 - Twisted-pair B+
- Pin 5 - Twisted-pair A-
- Pin 6 - Twisted-pair A+

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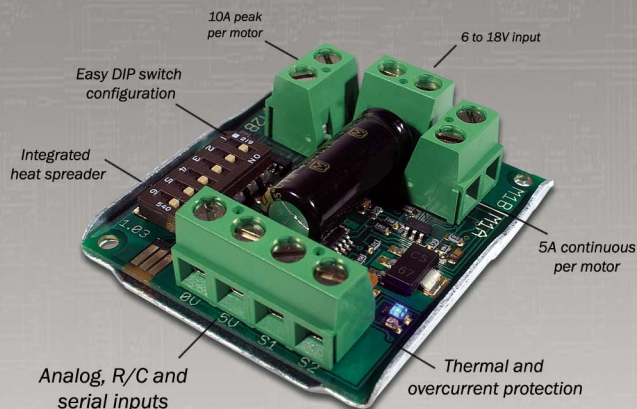
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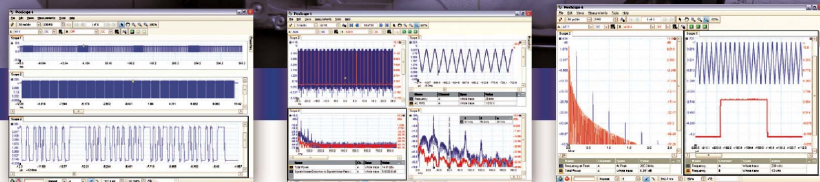
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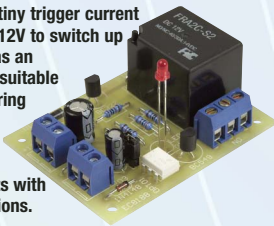
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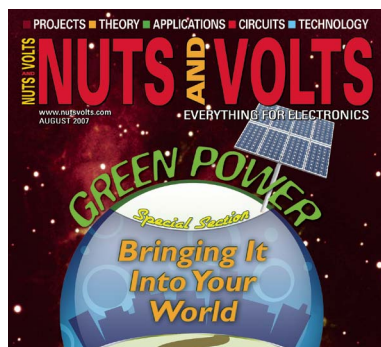
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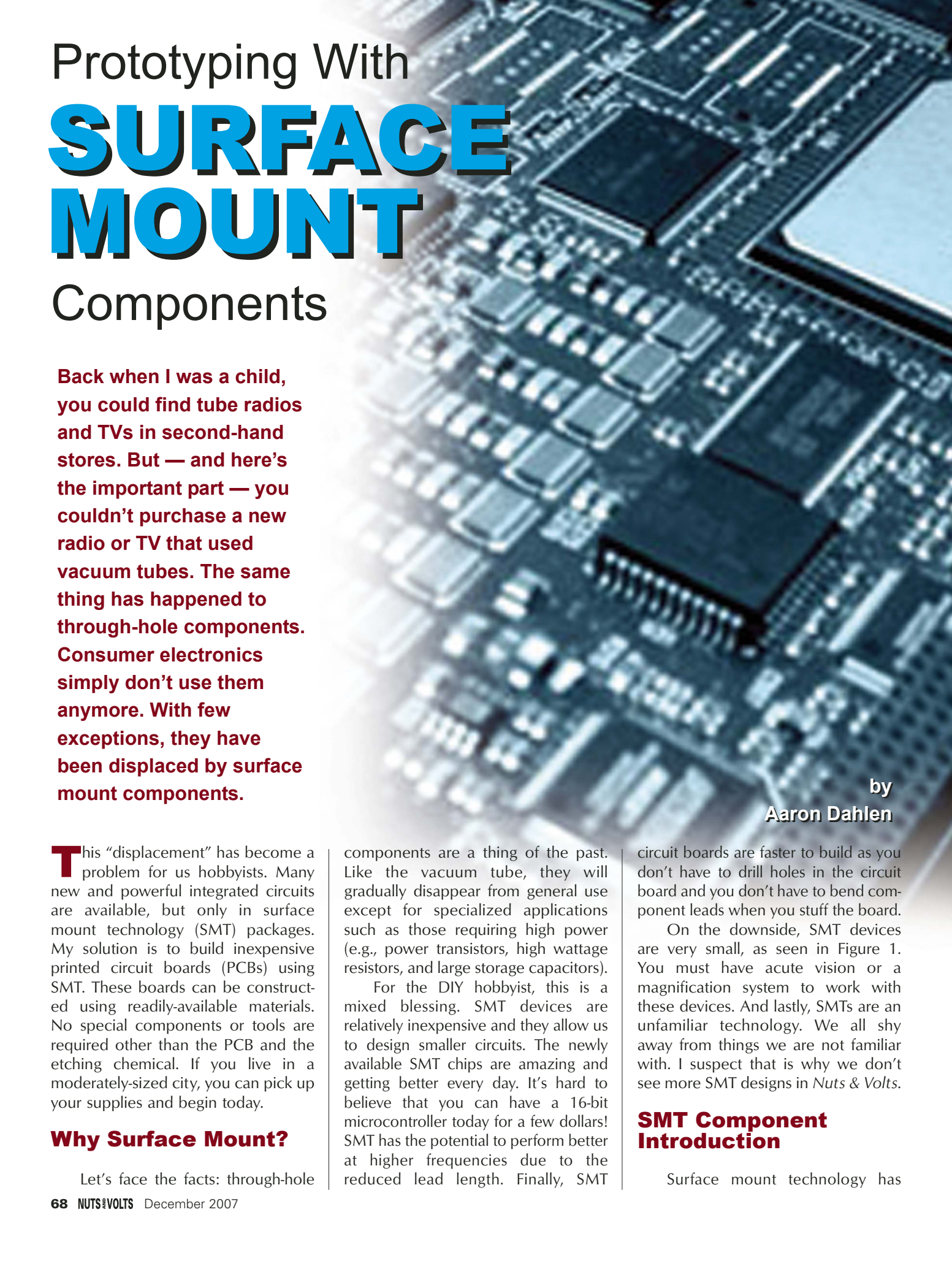
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Prototyping With **SURFACE MOUNT** Components

Back when I was a child, you could find tube radios and TVs in second-hand stores. But — and here's the important part — you couldn't purchase a new radio or TV that used vacuum tubes. The same thing has happened to through-hole components. Consumer electronics simply don't use them anymore. With few exceptions, they have been displaced by surface mount components.

by
Aaron Dahlen

This “displacement” has become a problem for us hobbyists. Many new and powerful integrated circuits are available, but only in surface mount technology (SMT) packages. My solution is to build inexpensive printed circuit boards (PCBs) using SMT. These boards can be constructed using readily-available materials. No special components or tools are required other than the PCB and the etching chemical. If you live in a moderately-sized city, you can pick up your supplies and begin today.

Why Surface Mount?

Let's face the facts: through-hole

components are a thing of the past. Like the vacuum tube, they will gradually disappear from general use except for specialized applications such as those requiring high power (e.g., power transistors, high wattage resistors, and large storage capacitors).

For the DIY hobbyist, this is a mixed blessing. SMT devices are relatively inexpensive and they allow us to design smaller circuits. The newly available SMT chips are amazing and getting better every day. It's hard to believe that you can have a 16-bit microcontroller today for a few dollars! SMT has the potential to perform better at higher frequencies due to the reduced lead length. Finally, SMT

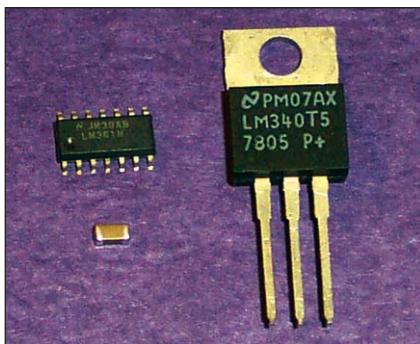
circuit boards are faster to build as you don't have to drill holes in the circuit board and you don't have to bend component leads when you stuff the board.

On the downside, SMT devices are very small, as seen in Figure 1. You must have acute vision or a magnification system to work with these devices. And lastly, SMTs are an unfamiliar technology. We all shy away from things we are not familiar with. I suspect that is why we don't see more SMT designs in *Nuts & Volts*.

SMT Component Introduction

Surface mount technology has

■ **FIGURE 1.** Surface mount compared to through-hole components. Shown is a 14-SOIC and a 1206 SMT package next to a TO-220 through-hole package.



been with us for over three decades. In this time, standards have emerged for device packages as seen in Figure 2. The SOT-23 package is used for general-purpose diodes and transistors. Power transistors are found in the SOT-223 case style. The Small Outline Integrated Circuit (SOIC) package is a standard for multi-pin ICs. Passive components such as resistors and capacitors are often found in case styles 805 and 1206.

This is a small sample of the packages available. For more information, look to the device data sheets. These are available from all manufacturers on the Internet. Large catalogs from the big suppliers are another place to learn about chips and packaging; check out Newark, Mouser, Allied, and others.

Circuit Board Introduction

Figure 3 shows a completed circuit board using the method outlined in this article. This particular PCB is a prototype circuit for an audio amplifier I am working on. It has two integrated circuits, five diodes, three transistors, 10 capacitors, and six resistors. This PCB could be physically smaller but this was not necessary for my needs. The following materials were used to construct the board:

- Computer running a CAD program. This circuit was drafted using Eagle Layout Editor available as limited free-ware from **CADSOFTUSA.com**. Eagle works on many types of computers. It even works on my old Pentium 233 MHz, albeit slowly. A Linux version is available. It allows you to quickly switch between the board and schematic so you can see the effect of schematic changes on the PCB.
- Transparency film available from your local office supply store.
- Laser printer. You must use a laser printer or copier. The toner is a critical component to this process ...

an inkjet printer will not work.

- Bare copper clad circuit boards.
- Chemical etchant. Ferric chloride or ammonium persulfate are both available from most electronic distributors.
- SMT components.
- Soldering iron with fine tip. I use a Weller WTCPT iron with a PTJ-7 conical tip.
- Fine solder (28 gauge).
- Flux.
- Desoldering braid.
- Tweezers. Use a style designed for SMT to prevent damage to the parts.
- Nail polish remover (acetone).
- Green scrubbing pad.
- Handheld magnifying glass for inspecting the finished solder joints.

Circuit Design

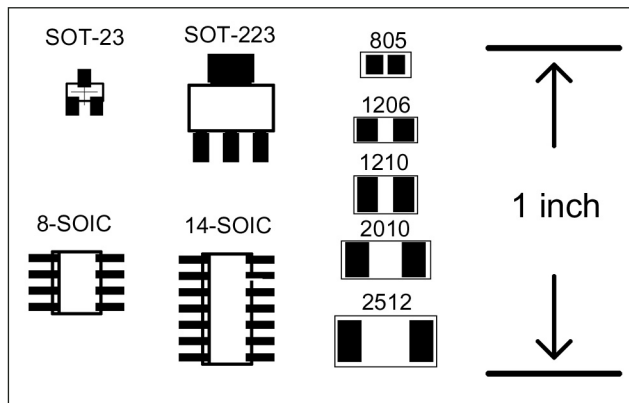
The first step in constructing a PCB is to enter the schematic into your CAD program.

Inspiration for circuit designs may be found in the device data sheets and application notes. Most semiconductor manufacturers maintain email lists to introduce new parts to subscribers. Many classical designs may be built using SMT. However, I will caution you to watch out for power dissipation: SMT parts don't have the surface area to get rid of heat and can burn up if you are not careful.

Design Layout

Design layout and circuit design are closely relat-

■ **FIGURE 3.** Completed SMT PCB. The large circles are used to connect the board to the remainder of the circuit.



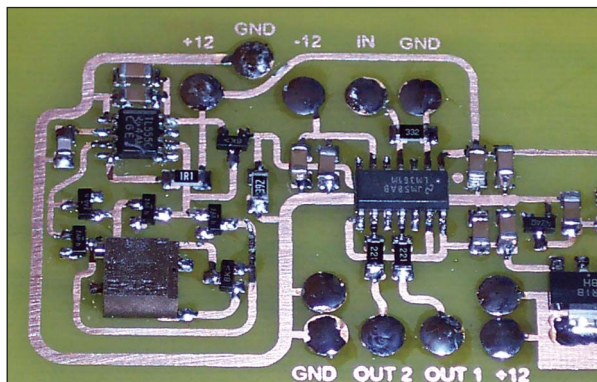
■ **FIGURE 2.** Typical SMT packages.

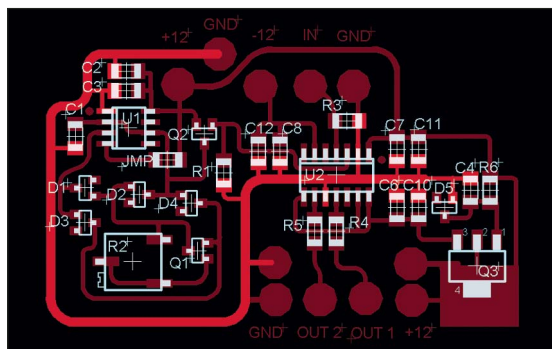
ed. When you are drawing the schematic, you are also selecting the component package as seen in Figure 4. For example, when you select an LM555N, you get an eight pin DIP package. When you select the LM555D, you get an eight-SOIC package. In both cases, the schematic symbol looks the same.

PCB design is an art form akin to playing a musical instrument. It will take time to develop your skill and you will get better with practice. As a starting point, I offer the following tips:

- Use larger SMT parts. The 1206 case size is a good starting point for resistors and capacitors. They are relatively easy to handle and can be seen without a magnification aid. Also, you can run a single trace between the component pads as shown in Figure 5. With this function, you can build single-sided boards that are compact with good circuit layout. Occasionally, you will need to use this technique to get around an important circuit trace. A low value resistor makes a good jumper.

- Read the documentation that came with the CAD program. Work through the design examples. Refer back to the documentation from time to





■ **FIGURE 4. Board layout using the EAGLE Layout Editor. The ground path is highlighted.**

haven't tried it yet. Smaller components are difficult to handle. Try to stay larger than the 805 case size.

- Optimize the circuit layout before turning on the autorouter. You will find that

circuit layout is an iterative process. You are always shuffling components to minimize wire length and detangle circuit paths. The autorouter will not do this for you. It only optimizes the wire run. If your parts placement is less than optimal, the wiring solution the autorouter provides will be atrocious. I've seen it route a ground wire in a loop covering half the board. This bad wiring will likely result in oscillations in analog circuits and random logic errors in digital circuits.

- You can verify layout and clearances by printing the design to paper and comparing the actual components to the artwork.

- Connection to the board can be simple pads (large circles) as shown in Figure 3. SMD connectors are available or you can use through-hole parts.

Toner Transfer

The PCB traces are developed using a masking process. A mask is applied to the PCB to "save" the copper as shown in Figure 6. The board is then exposed to an etching chemical. All the copper that is not protected by the mask is etched away. Our goal is to make a good mask.

The toner transfer method is a fast, easy method to place the mask onto the PCB. It

■ **FIGURE 6. Preparations for toner transfer. The PCB and the transparency are both taped to the table.**

yields good results if you are careful and don't rush. Using this design process, your circuit is printed to an 8-1/2 x 11 inch piece of transparency film. The film is then placed on the copper board and heated as shown in Figure 6. The toner on the film transfers to the PCB, creating a mask as in Figure 7. The following steps are required:

1. Print the circuit design to a sheet of transparency film using a laser printer or a copier. Remember, inkjet technology will not work as it has no toner to transfer. Go to the setup page in your printer driver and select the mirror image option. Print to the smooth side of the transparency film. This allows the toner to be easily transferred to the PCB. Be sure to select "black" in the printer properties so that you have solid lines.

2. Clean the PCB. You can clean the board mechanically using a green scrubbing pad. The rough surface gives the toner a place to adhere and removes any oxidation.

3. Tape the board and transparency to a table as demonstrated in Figure 6. Cover with a piece of paper. The paper acts to slow the heating process and spread the heat evenly. You do not want to apply the iron directly to the transparency film because it will yield poor results.

4. Heat the PCB and transparency film with a clothes iron. Use a constant motion and let the weight of the iron do the work. Don't push down on it.

5. Inspect the transparency every 30 seconds. This is the advantage of using a transparent film. You can actually see the toner to determine your progress. Stop heating when the toner melts. It will take some experimentation to get the process correct. If you make a mistake, you can start over again.

6. Don't move the transparency or the board until they are cool to the touch. If you don't wait, you will have a black stringy mess to clean up.

7. Touch-up may be necessary — Use a Sharpie pen to add/modify traces or an X-Acto knife to remove material.

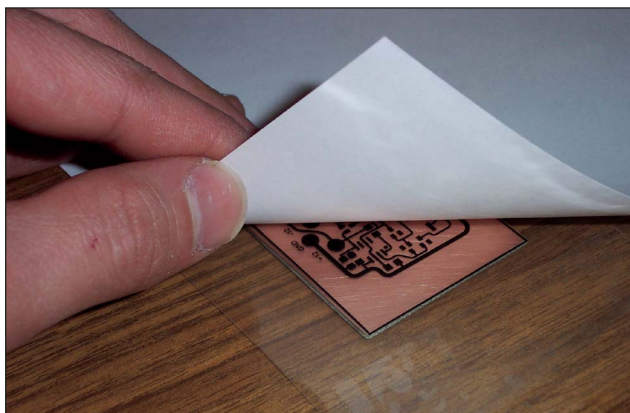
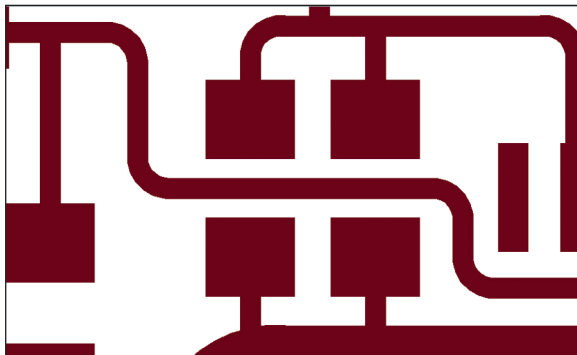
time to learn new tricks.

- Most SMT parts are contained in the standard parts library. If not, refer to the device data sheet for the recommended pad layout.

- Try to use a short, thick, direct ground path for your circuit. The ground path is highlighted in Figure 4. Actually, try to use short paths for all your circuit traces.

- Don't go too small. The toner transfer process isn't 100% accurate. You may be able to use this process with SSOIC (shrink SOIC) chips, but I

■ **FIGURE 5. Routing a trace beneath larger SMT components. The pads are for 1206 SMT capacitors and the wire width is 0.016 inches.**



■ FIGURE 7. PCB ready for etching.

Etching

Etch the board using the instructions supplied with the etching chemical. Be sure to use personal protective equipment. You don't want to splash chemicals into your eyes. Also, the chemical will stain everything it touches, including your hands and clothes. Ferric chloride does not come out in the wash!

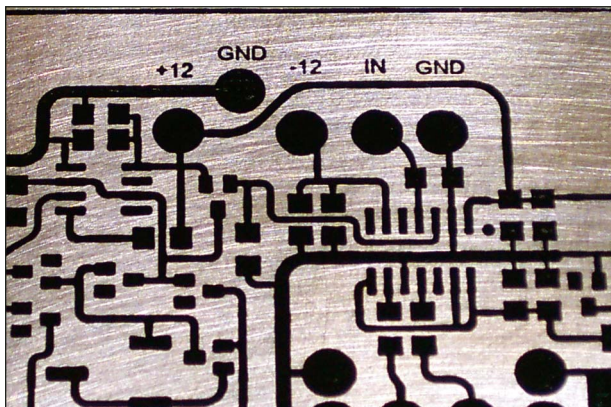
After the board is etched, you can remove the toner mask using mechanical or chemical means. Nail polish remover (acetone) and a green scouring pad do the trick. It takes a bit of elbow grease to remove the toner. You may want to experiment with more aggressive chemicals.

Soldering

Once you have a clean board, you are ready to solder your SMT components. It doesn't take long to acquire soldering skills. Here's a quick run down:

1. Apply a small amount of flux to the pads you are going to solder (optional).
2. Apply a small amount of solder to one pad (for ICs, use pin 1).
3. Remove the SMT component from its protective tape and position the part using tweezers.
4. Remelt the solder from Step 2 while holding the part with tweezers. The part will sink into the solder.
5. Solder the other connections.
6. Use a solder wick to remove solder bridges.
7. Clean the flux off using a solvent (optional).

Since most of your boards will be



prototypes, it is best to build and debug as you go. Small sections are much easier to debug than entire circuit boards.

The finished product will look like the board in Figure 3. Notice that there are open copper runs. You can leave these as they are, run solder over the runs, or apply a sealant to the entire board. Personally, I leave them as they are since it doesn't affect performance.

Parts Kits

Each of us has a stash of components we have collected over the years. A good way to procure your SMT components is to purchase kits. I purchased an assortment of 1/4W (1206) 5% resistors from Digi-Key (part #PHE2A-KIT). This has a good value. You may also scavenge some SMT components from old equipment. Be sure to test them before you use them.

Conclusion

I trust this article demonstrates that you can build and design with SMT devices. Once you start, you will appreciate the speed at which you can make a quality circuit. You will also reap the benefit of being able to use many of the newer integrated circuits. **NV**

AUTHOR BIO

■ Aaron Dahlen is devoted to his family and country. He serves in the US Military and is currently somewhere above the Arctic Circle. In the little spare time he has, he enjoys experimenting and designing electronics. You may reach him via email at APDahlen@gmail.com

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Basic Analog Power Supply Design

by Gerard Fonte

Part 1

There is the old saying:

“You can give a man a fish and he will eat for a day or you can teach a man to fish and he will eat forever.”

There are many articles that give the reader a specific design for building a power supply. And it must be made clear that there is nothing wrong with these cook-book designs. They often have very good performance. But they don’t teach the readers how to design a power supply by themselves. This two-part article will start from the beginning and explain every step necessary to build a basic analog power supply. The design will focus on the ubiquitous “three-terminal regulator” and include a number of enhancements to the basic design.

It is always important to remember that the power supply — either for a particular product or as a general piece of test equipment — has the potential to electrocute the user, start a fire, or destroy the device it is powering. Obviously, these are not good things. For that reason, it is critical to approach this design conservatively. Provide plenty of margin for components. A well-designed power supply is one that is never noticed.

Input Power Conversion

Figure 1 shows the fundamental design for a typical analog power supply. It consists of three main components: Input power conversion and conditioning, rectification and filtering, and regulation. The input power conversion is typically a power transformer and is the only method considered here. However, there are a couple of points

that are important to mention.

The first is that 117 VAC (Volts Alternating Current) is really an RMS (Root Mean Square) measurement. (Note that I have seen ordinary household power specified anywhere from 110 VAC to 125 VAC. I just measured mine and found it to be precisely 120.0 VAC.) An RMS measurement of a sine wave is much lower than the actual peak voltage and represents the equivalent DC (Direct Current) voltage needed to provide the same power. The RMS conversion varies according to the wave shape and for a sine wave the value is 1.414. This means that the deviation around zero volts is actually 169.7 volts (for my 120 VAC power). The power goes from -169.7 volts to +169.7 volts each cycle. Therefore, the peak-to-peak voltage is actually 339.4 volts!

This voltage becomes especially important when adding bypass capacitors to the main power lines to suppress noise from entering or leaving the power supply (a common situation). If you think the actual voltage is 120 volts, you may use 150 volt capacitors. As you

FIGURE 1. A basic analog power supply consists of three parts. The first two are discussed in this article and the last in the next installment.

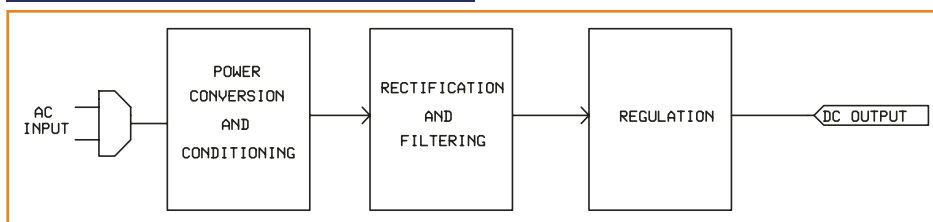


FIGURE 2. The input conditioning is pretty basic, but it must be remembered that the RMS voltage is not the same as the peak voltage. The peak voltage of 120 VAC RMS is about 170 volts.

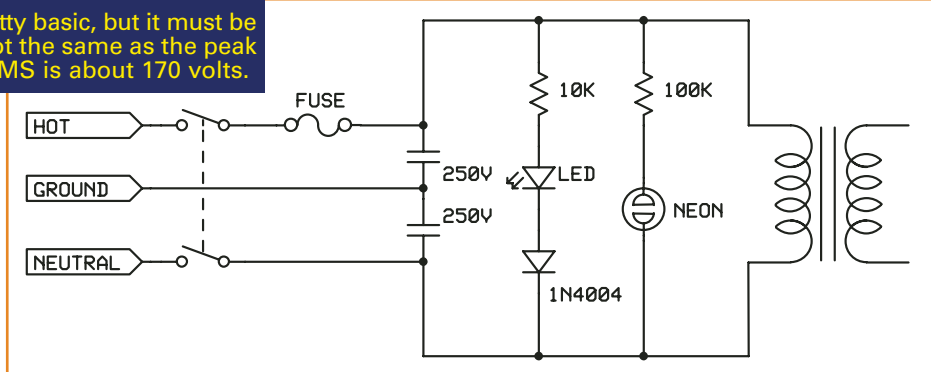
can see, this is not correct. The absolute minimum safe working voltage for your capacitors is 200 volts (250 volts is better). Don't forget that if you expect to see noise/spikes on the line, you need to add that noise/spike voltage to the peak voltage.

The input frequency is universally 60 Hz in the USA. In Europe, 50 Hz is common. Transformers rated for 60 Hz will generally perform well on 50 Hz and vice versa. Additionally, the frequency stability of the power line is usually excellent and is rarely a consideration. Occasionally, you may find 400 Hz transformers available. These are typically military or aeronautical devices and are generally not suitable for use on 50/60 Hz power (or vice versa).

The output of the transformer is also specified as an RMS voltage. Additionally, the voltage specified is the minimum voltage expected under full load. Often there is about a 10% increase in the rated output with no-load. (My "25.2 volt/two-amp" transformer measures 28.6 volts with no load.) This means that the actual no-load, peak output voltage for my "25.2 volt" transformer is 40.4 volts! As you can see, it is always important to remember that the rated RMS voltages for AC power are substantially less than the actual peak voltages.

Figure 2 provides a typical input power conversion and conditioning design. I prefer to use a double-pole switch although it is not absolutely necessary. It protects against mis-wired electrical outlets (which is rare today) or mis-wired power leads in the power supply itself (much more common). It is vital that when the power switch is off, the hot lead is disconnected from the power supply.

The fuse (or circuit breaker) is necessary. Its main purpose is to prevent fires because, without it, a transformer or primary circuit short will allow massive currents to flow causing metal parts to get red or even white hot. It is usually a slow-blow type rated at 250 volts. The current rating should be about double of what the transformer



can expect to draw. For example, the 25.2 volt two-amp transformer mentioned above will draw about 0.42 amps of primary current (25.2 volts/120 volts x two amps). So, a one amp fuse is reasonable. A fuse in the secondary will be discussed in the next article.

The bypass capacitors help to filter out noise and are optional. Since the peak voltage is about 170 volts, a 250 volt rating is better than a marginal 200 volt rating. You may want to use a "power-entry filter." There are many types of these units. Some contain a standard power connector, switch, fuse holder, and filter in one small package. Others may have only some of these components. Typically, the ones with everything are fairly expensive, but surplus units can usually be found at very reasonable prices.

Being able to determine if the primary circuit is powered is important so a pilot light is used. Two typical circuits are shown. The neon lamp has been used for decades. It is simple and inexpensive. It has the drawbacks that it is somewhat fragile (being made of glass), can flicker if the resistor is too big, and can actually generate some electrical noise (due to the sudden ionic breakdown of the neon gas).

The LED circuit also requires a current limiting resistor. At 10,000 hms, about 12 mA of current is provided. Most LEDs are rated for a maximum current of 20 mA, so 12 mA is reasonable. (High efficiency LEDs may work satisfactorily with only 1 or 2 mA, so

the resistor can be increased as required.)

Note that LEDs have really poor reverse breakdown voltages (typically 10 to 20 volts). For that reason, a second diode is necessary. This must be able to operate with at least 170 volts of PIV (Peak Inverse Voltage). The standard 1N4003 is rated at 200 PIV which doesn't provide much margin. The 1N4004 is rated at 400 PIV and costs perhaps a penny more. By placing it in series with the LED, the overall PIV is 400 plus the LED PIV.

Rectification and Filtering

Figures 3, 4, and 5 show the most typical rectification circuits with the

FIGURE 3. The half-wave rectifier circuit is simple but it produces a poor output waveform that is very difficult to filter. Additionally, half of the transformer power is wasted. (Note that the filtering capacitors are omitted for clarity because they change the waveform.)

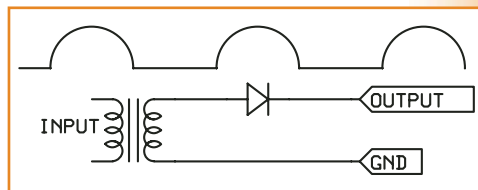
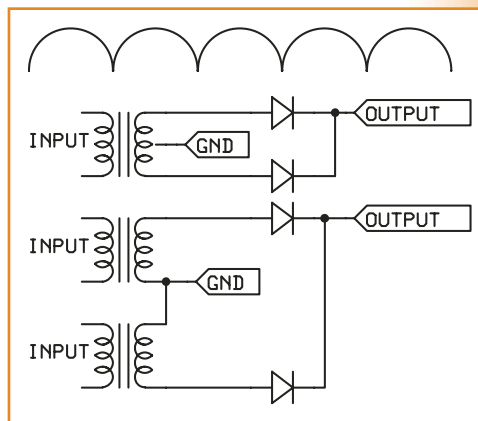


FIGURE 4. The full-wave design (top) produces a nice output. But by redrawing the circuit (bottom), it can be seen that it is really just two half-wave rectifiers connected together. Again, half the transformer power is wasted.



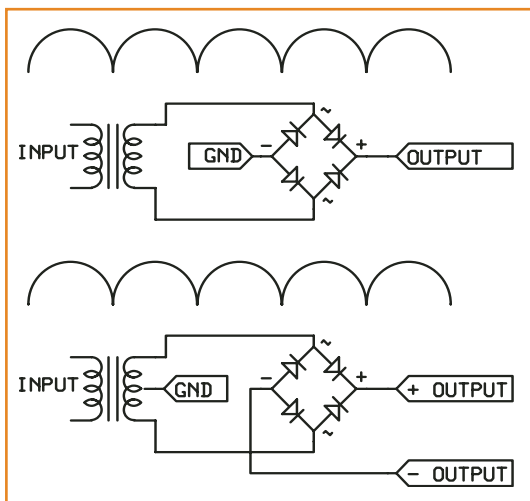


FIGURE 5. The bridge rectifier approach (top) provides full use of the transformer power and with a full-wave rectification. Additionally, by changing the ground reference (bottom), a dual voltage power supply can be obtained.

output waveform displayed above. (The filter capacitor is not shown because by adding it, the waveform changes to something like a DC voltage.) It is useful to examine these three basic circuits to identify the strengths and weaknesses of them.

Figure 3 shows the basic half-wave rectifier. The only redeeming characteristic of this is that it is very simple, using only a single rectifier. The bad feature is that it uses only half of the power cycle making the theoretical efficiency of the circuit less than 50% just to start. Often, half-wave rectifier power supplies are only 30% efficient. Since transformers are expensive items, this inefficiency is very costly. Secondly, the wave shape is very difficult to filter. Half the time there is no power at all coming from the transformer. Smoothing the output requires

very high values of capacitance. It is rarely used for an analog power supply.

An interesting and important thing happens when a filter capacitor is added to a half-wave rectifier circuit. The no-load voltage differential doubles. This is because the capacitor stores energy from the first half (positive part) of the

cycle. When the second half occurs, the capacitor is holding the positive peak voltage and the negative peak voltage is applied to the other terminal causing a full peak-to-peak voltage to be seen by the capacitor and through that, the diode. Thus, for a "25.2 volt" transformer above, the actual peak voltage seen by these components can be over 80 volts!

Figure 4 (top circuit) is an example of a typical full-wave, center-tap rectifier circuit. This is used today even though, in most cases, it probably shouldn't be. It provides a nice output that is fully rectified. This makes filtering relatively easy. It uses only two rectifiers, so it's pretty inexpensive. However, it is no more efficient than the half-wave circuit presented above.

This can be seen by re-drawing the circuit with two transformers (Figure 4

bottom). When this is done, it becomes clear that the full-wave is really just two half-wave circuits connected together. Half of each transformer power cycle is not used. Thus, the maximum theoretical efficiency is 50% with real efficiencies around 30%.

The PIV of the circuit is one half of the half-wave circuit because the input voltage to the diodes is half of the transformer output. The center tap provides half the voltage to the two ends of the transformer windings. So, for the 25.2 volt transformer example, the PIV is 35.6 volts plus the no-load increase which is about 10% more.

Figure 5 presents the bridge rectifier circuit which should generally be the first choice. The output is fully rectified so filtering is fairly easy. But most importantly, it uses both halves of the power cycle. This is the most efficient design and gets the most out of the expensive transformer. Adding two diodes is much less expensive than doubling the transformer power rating (measured in "Volt-Amps" or VA).

The only drawback to this design is that the power must pass through two diodes with a resulting voltage drop of 1.4 volts instead of 0.7 volts for the other designs. Generally, this is only a concern for low voltage power supplies where the additional 0.7 volts represents a substantial fraction of the output. (In such instances, a switching power supply is usually used rather than either of the above circuits.)

Since there are two diodes being used for each half-cycle, only half of the transformer voltage is seen by each. This makes the PIV equal to the peak input voltage or 1.414 times the transformer voltage, which is the same as the full-wave circuit above.

A very nice feature of the bridge rectifier is that the ground reference can be changed to create a positive and negative output voltage. This is shown in the bottom of Figure 5.

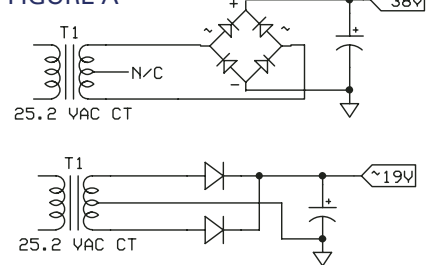
A Note on Efficiency

Let me explain the difference between a full-wave rectifier design and a bridge, especially from the point of view of efficiency.

Remember that I said half the power is wasted with a full-wave rectifier design. It is self-evident if you consider that a full-wave design is really made up of two half-wave designs. Combining two circuits that are each about 50% efficient does not in any way increase the total efficiency of the circuit. It's still about 50% overall.

The loss of efficiency comes from the amplitude of the resultant rectification. A half-wave circuit clearly provides half the amplitude that is available from the transformer. So does the full-wave version, but it's not as obvious. It only uses half of the total available voltage of the transformer. The output of the full-wave rectifier is 1.414 times the voltage between the center tap and the end. The output of a bridge is the full end-to-end voltage of the transformer times 1.414. This is shown in the attached figure. For the 25.2 volt transformer, the full-wave rectifier develops about 19 volts (unloaded). The bridge rectifier develops about 38 volts (unloaded). So, the full-wave rectifier does indeed waste about half the available power from the transformer.

FIGURE 4



Filtering

Nowadays, nearly all filtering for an analog power supply comes from a filter capacitor. It is possible to use an inductor in series with the output, but at 60 Hz, these inductors must be quite large

and are expensive. Occasionally, they are used for high-voltage power supplies where suitable capacitors are expensive.

The formula for calculating the filter capacitor (C) is quite simple, but you need to know the acceptable peak-to-peak ripple voltage (V), half-cycle time (T), and current drawn (I). The formula is $C = I \cdot T / V$, where C is in microfarads, I is in milliamps, T is in milliseconds, and V is in volts. The half-cycle time for 60 Hz is 8.3 milliseconds (reference: 1997 *Radio Amateur's Handbook*).

It is clear from the formula that the filtering requirements are increased for high current and/or low ripple power supplies. But this is just common sense. An easy-to-remember example is 3,000 microfarads per ampere of current will provide about three volts of ripple. You can work various ratios from this example to provide reasonable estimates of what you need fairly quickly.

One important consideration is the surge of current at turn-on. The filter capacitors act as dead shorts until they get charged up. The larger the capacitors, the greater this surge will be. The bigger the transformer, the greater the surge will be. For most low voltage analog power supplies (<50 volts), the transformer winding resistance helps somewhat. The 25.2 volt, two amp transformer has a measured secondary resistance of 0.6 ohms. This limits the maximum inrush to 42 amps. Additionally, the inductance of the transformer reduces this somewhat. However, there is still a large potential current surge at turn-on.

The good news is that modern silicon rectifiers often have huge surge current capabilities. The standard 1N400x family of diodes is usually specified with

30 amps of surge current. With a bridge circuit, there are two diodes carrying this so worst-case is 21 amps each which is below the 30 amp specification (assuming equal current sharing, which is not always the case). But, this is an extreme example. Generally, a factor of about 10 is used, instead of 21.

Nevertheless, this current surge is not something to be ignored. Spending a few cents more to use a three-amp bridge instead of a one-amp bridge may be money well spent.

Practical Design

We can now put these rules and principles to use and start to design a basic power supply. We will use the 25.2 volt transformer as the core of the design. Figure 6 can be seen as a composite of the previous figures but with practical part values added. A second pilot light in the secondary indicates its status. It also shows if there is a charge on the capacitor. With such a large value, this is an important safety consideration. (Note that since this is a DC signal, the 1N4004 reverse voltage diode is not needed.)

It may be cheaper to use two smaller capacitors in parallel than one large one. The working voltage for the capacitor must be at least 63 volts; 50 volts is not enough margin for the 40 volt peak. A 50 volt unit provides only 25% margin. This may be fine for a non-critical application, but if the capacitor fails here, the results can be catastrophic. A 63 volt capacitor provides about 60% margin while a 100 volt device gives 150% margin. For power supplies, a general rule of thumb is between 50% and 100% margin for the

Circuit	Filter Needs	PIV Factor	Transformer Use
Half-Wave	Large	2.82	50% (theoretical)
Full-Wave	Small	1.414	50% (theoretical)
Bridge	Small	1.414	100% (theoretical)

TABLE 1. A summary of the characteristics of the various rectifier circuits.

rectifiers and capacitors. (The ripple should be about two volts, as shown.)

The bridge rectifier must be able to handle the high initial current surge. A two-amp unit costs about \$0.57, a four-amp bridge is \$0.77, and a six-amp device is \$0.87. It seems obvious that spending an additional dime for improved reliability is worthwhile. Note that the bridge is specified by what the transformer can supply rather than what the power supply is eventually specified for. This is done in case there is an output short. In such a case, the full current of the transformer will be passed through the diodes. Remember, a power supply failure is a bad thing. So design it to be robust.

Conclusion

Details are an important consideration in designing a power supply. Noting the difference between RMS voltage and peak voltage is critical in determining the proper working voltages for the supply. Additionally, the initial surge current is something that cannot be ignored.

Next month, we will complete this project by adding a three-terminal regulator. We will design a general-purpose, current-limited, adjustable voltage power supply with remote shut-off. Additionally, the principles used for this design can be applied to any power supply design. **NV**

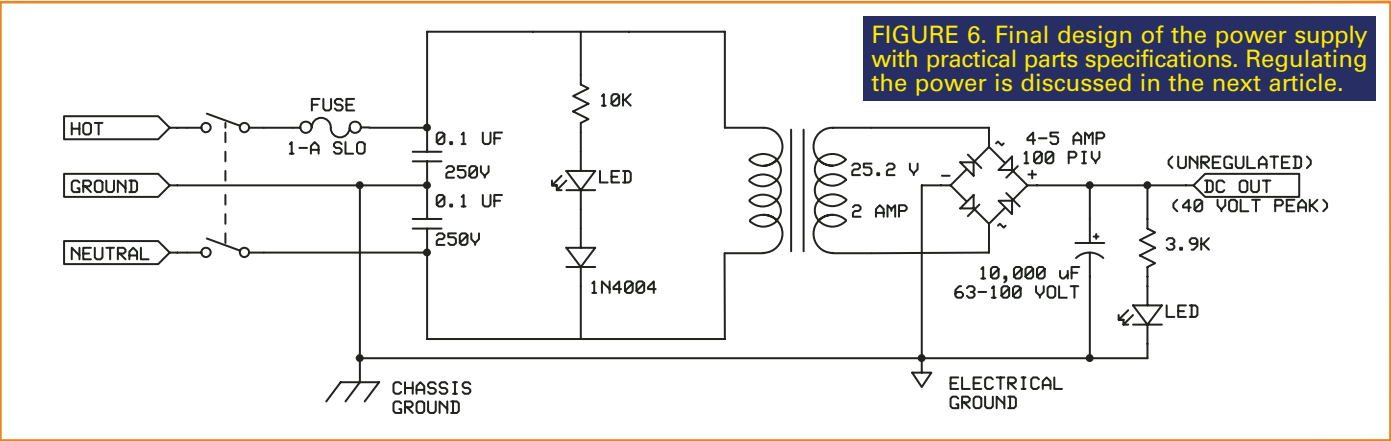


FIGURE 6. Final design of the power supply with practical parts specifications. Regulating the power is discussed in the next article.

■ BY FRED EADY

ORDERING DRINKS OVER THE 'NET

OVER THE LAST COUPLE OF YEARS, I've had the opportunity to host a number of educational sessions at the Microchip MASTERS conference in Arizona. It was my job to teach the students how to meld the various Internet protocols with Microchip's PIC microcontrollers.

If you've been keeping up with Design Cycle, we've been implementing Internet protocol code with PICBASIC PRO and in the rush you have been exposed to a variety of the Internet protocols and the PICs they run under. However, there is one Internet protocol that we have yet to discuss. That particular protocol is the most often spoken about protocol used in general conversation and the least truly understood protocol of them all. You guessed it. The "missing" protocol is TCP. To help the students in the MASTERS classes better understand TCP, I related the following story to them.

Being a Southern boy, my sensitive ears have been party to many a conversation concerning moonshine and the production of said spirit. Moonshine needs no introduction to most anyone that lives in the United States. However, I did find some of the foreign MASTERS attendees needed a little help with the moonshine concept. Not all of the out-of-country MASTERS students I encountered had trouble with the word "moonshine" as I received a neat email from one of my South African students describing in detail how South African "shine" was produced. Once everyone in the room was comfortable with traditional Southern "moonshine," I introduced my cast of characters and the story behind their existence. (If your name is Bubba, please don't be offended with my Bubba character since in the South, the name Bubba and the word moonshine seem to always bubble to the top when things illegal occur outside of the city limits.) With that, let's get on with the story.

UDP is considered a "connectionless" protocol and therefore is inherently unreliable. In simple terms, that means that UDP uses a best-effort process to communicate and doesn't need a formal session to attempt to transfer data from Point A to Point B. Consider this real-world situation. PawPaw is sitting on his front porch enjoying the cool fall breeze and discovers he has taken the last sip of moonshine in the jug beside his rocking chair. Bubba is within earshot, feeding the hogs down in the barn yard. PawPaw knows he's there and hollers out to Bubba, "Bubba! Go down to the still and bring me a jug of shine!"

PawPaw doesn't know if Bubba hears him or not. If Bubba hears PawPaw and does what he is told to do, PawPaw will receive a jug of moonshine from Bubba pretty soon. On the other hand, if Bubba didn't hear PawPaw, no moonshine will be forthcoming.

Let's assume that Bubba did not hear PawPaw. Thus, a thirsty PawPaw sits and waits patiently and not one drop of moonshine is delivered to him. If PawPaw really wants another sip of shine, he'll holler at Bubba again hoping that this time Bubba hears him. The amount of moonshine Bubba may deliver depends on what Bubba really hears and understands. What if Bubba hears "slug" instead of "jug?" PawPaw won't be happy very long. If Bubba does indeed hear PawPaw, he doesn't have to holler back to PawPaw if he doesn't want to. However, Bubba, being raised right, will respect his elder and go fetch the jug of "shine" for PawPaw.

In the previous example, PawPaw has used the UDP protocol to attempt to send a message to Bubba and, in turn, receive the desired result — a jug of moonshine. As I mentioned earlier, UDP is a best-effort protocol and works perfectly most of the time. However, there is absolutely no guarantee that the UDP message payload will be delivered intact to the intended receiver. With that, let's take the same "out-of-shine" scenario and have PawPaw use TCP concepts instead of UDP concepts. Unlike the UDP method, TCP requires PawPaw to establish a communications session with Bubba before Bubba can be commanded to fetch him a new jug of "shine." Here we go.

PawPaw yells for Bubba. If Bubba hears PawPaw, he hollers back "What chu want, PawPaw?" Assuming PawPaw has his hearing aid in, PawPaw hears Bubba's positive acknowledgement and hollers back his intent, "Bubba, I need some "shine" from the still!" Bubba again hears PawPaw and replies, "Okay ... how much?" PawPaw again asks for a jug of moonshine from the still. Bubba hears this request and replies, "Let me git this straight. You want me to go git you a jug of "shine" from the still." PawPaw hollers back, "Yep!" At this point, Bubba hops in the pickup truck, drives down to the creek, walks down to the creek house

■ **SNIFFERSHOT 1.** If you set your breakpoints carefully, you can see this TCP packet embedded within the PIC's SRAM. The SYN flag is considered a byte of data in this handshake sequence.

still, and fetches PawPaw's refreshment. After a few minutes, PawPaw's jug is renewed.

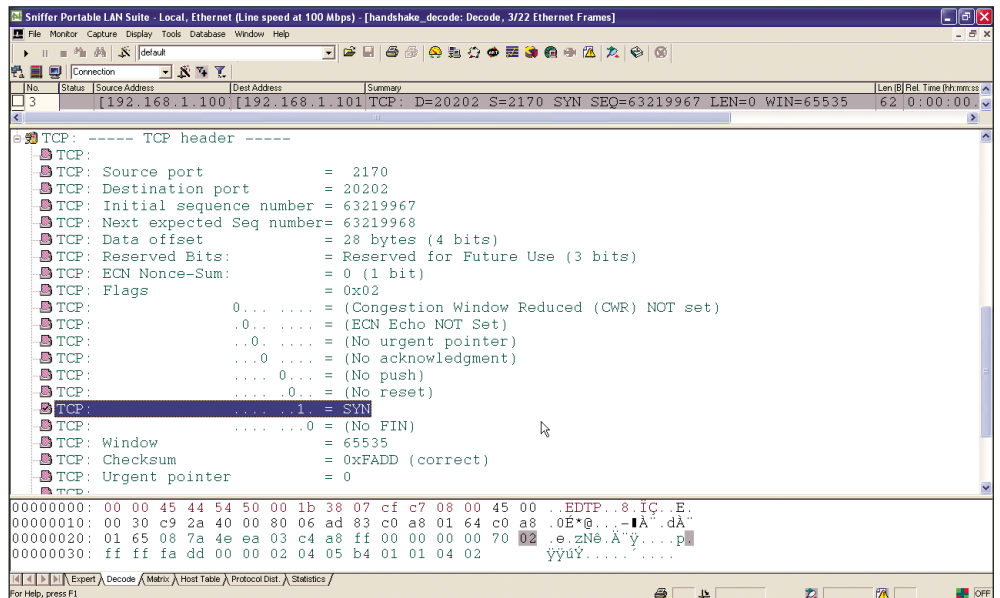
In this case, PawPaw established a communications session with Bubba. Once the communications session was established, Bubba made sure that he understood PawPaw correctly and proceeded to carry out PawPaw's command. The communication session between PawPaw and Bubba officially ended when Bubba delivered the jug of shine. Bubba, his job done, went back to the barn to finish feeding the hogs. This is how TCP works.

FETCHING "SHINE" WITH A PIC

Let's replace PawPaw with a laptop running Telnet and Bubba with a PIC running a miniature TCP application. Instead of fetching moonshine, our goal will be to receive an echo of every character we send from the laptop client to the PIC server. We already have the hardware in place in the form of the EDTP Ethernet MINI. So, all we need to do is to tap out some TCP driver code. Up to this point, we've been using PICBASIC PRO. This time around, we'll still employ the services of PICBASIC PRO but instead of using the 16 bit version, we'll upgrade to the new 32 bit version of PICBASIC PRO, which is invoked by calling the PBPL executable. Our new spin of TCP code requires the manipulation of 32 bit values and thanks to PBPL, we won't have to code up any "32 bit fake-out" routines, which will also make the new TCP code set easier for you to follow.

We will not be modifying any of the code we've written thus far. The TCP module will be an addition to the code we have already produced. Incoming Ethernet frames will be handled just as they were before. However, now we will branch to a real TCP code module rather than

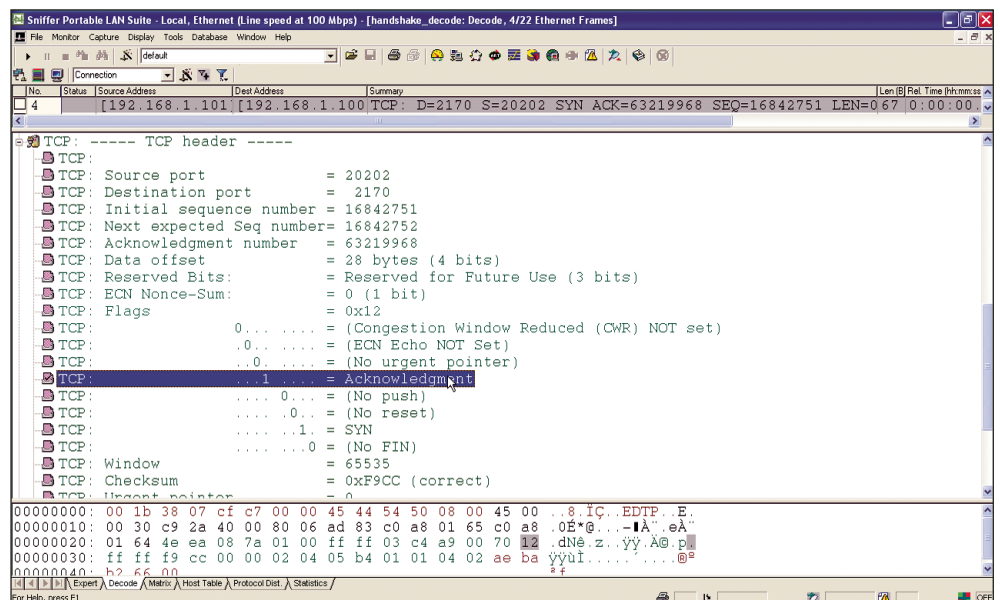
■ **SNIFFERSHOT 2.** Three major events occur in the second handshake. The incoming SYN is acknowledged, the EDTP Ethernet MINI sends its initial sequence number, and the SYN and ACK flags are set in the outgoing packet.

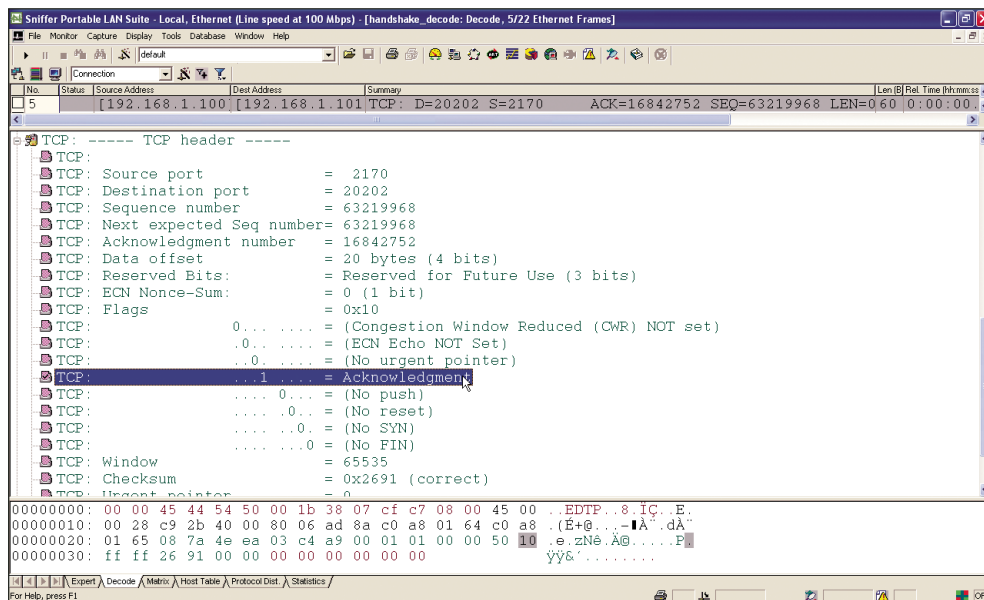


just perform the gosub to an empty TCP subroutine that right now only contains a single return instruction.

The recent addition of a PICBASIC PRO DHCP module to our EDTP Ethernet MINI driver eliminates the need to hardcode an EDTP Ethernet MINI IP address. However, like UDP, TCP requires us to define at least one port address. We must leave our old port address buddy 8088 behind as the new version of the Network General Sniffer Portable automatically identifies our old port address value of 8088 decimal with an HTTP component. Rather than disable this very nice feature of Sniffer Portable, I simply assigned 20202 decimal (\$4EEA hexadecimal) as our new local TCP port address.

TCP session establishment depends on keeping up with some 32 bit numbers and a set of TCP flags. PBPL has the 32 bit job covered and the flag recognition and manipulation activities are left to us. Here's how we define the TCP flags:





```

;*****
;*      TCP Flags
;*      IN flags represent incoming bits
;*      OUT flags represent outgoing bits
;*****
FIN_IN      CON  $01
SYN_IN      CON  $02
RST_IN      CON  $04
PSH_IN      CON  $08
ACK_IN      CON  $10
URG_IN      CON  $20
FIN_OUT     CON  $01
SYN_OUT     CON  $02
RST_OUT     CON  $04
PSH_OUT     CON  $08
ACK_OUT     CON  $10
URG_OUT     CON  $20

```

As we assemble our TCP code module, you'll become very familiar with the SYN and ACK flags as they are instrumental in establishing a communications session between a client and a server. The FIN and PSH flags will

■ **SNIFFERSHOT 3.** All of the numbers have been exchanged. It's time to rock and roll TCP style.

come into play when we code the PICBASIC PRO HTTP module.

You should already be familiar with how the EDTP Ethernet MINI PICBASIC PRO driver gets and processes an incoming packet. You also should know that an ARP request and ARP response occur before anything else to allow the players to identify each other by unique IP and hardware (MAC) addressing. So, let's look at what happens next in the TCP world.

On my laptop (which is running Bill's Windows XP Professional), I brought up a command window and entered the word Telnet. Once

I received the Microsoft Telnet banner, I entered:

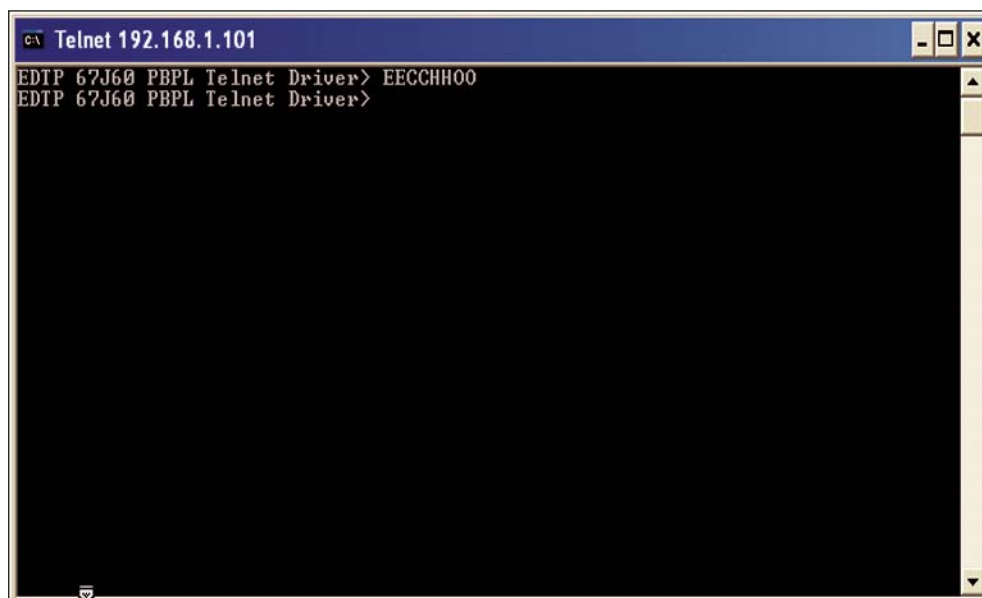
OPEN 192.168.1.101 20202

My little EDTP Ethernet MINI network consists of a Linksys Cable/DSL Router tied to a Linksys Five-Port Workgroup Switch. The IP address I entered in the Telnet window was supplied by the router via DHCP to the EDTP Ethernet MINI. My laptop received an IP address of 192.168.1.100. Recall that 20202 is our EDTP Ethernet MINI's TCP port address.

There is a method to my madness of connecting a router with a perfectly good built-in four-port switch to a separate five-port Ethernet switch. The router's switch ports refuse to deliver certain types of network traffic (some ARP and HTTP traffic in particular) between the peers connected to its switch ports. Thus, I use the router only as a DHCP server and rely on the external five-port switch to interconnect the EDTP Ethernet MINI server to the client laptop and Sniffer Portable laptop.

If you have access to a static IP setup, all you have to do is open up a channel in your router to redirect incoming TCP, UDP, and HTTP traffic from the real Internet to the EDTP Ethernet MINI's IP address. Since we are never really going beyond our little five-port switch and we are using IP addresses that cannot be routed on the Internet (192.x.x.x), we must employ my switch-and-router networking setup.

Let's examine Sniffershot 1. The first thing we learn is the client laptop's TCP port address, which is 2170 decimal. We know early on



■ **SCREENSHOT 1.** Everything is running according to the plan. Note the echoed characters in this shot.

■ **SNIFFERSHOT 4.** Note that the Sniffer Portable application calculates lots of things automatically for the user. For instance, the Next expected Seq number field is not an actual part of the TCP packet. It's put there by the Sniffer Portable application to help you troubleshoot TCP communications problems.

that this packet is aimed at the EDTP Ethernet MINI because we set the EDTP Ethernet MINI's TCP port address to 20202 decimal in our driver code. The sequence of bytes we are studying in Sniffershot 1, the client laptop is trying to establish a communications session with the EDTP Ethernet MINI server. Note that the client laptop has forwarded its initial 32 bit sequence number to the EDTP Ethernet MINI and is expecting the MINI to acknowledge the receipt of a single byte of data. In this case, no data is actually transmitted and the SYN flag is considered as the byte of data. The client laptop's transmission of this SYN flag with no data is the first handshake of the three-way process.

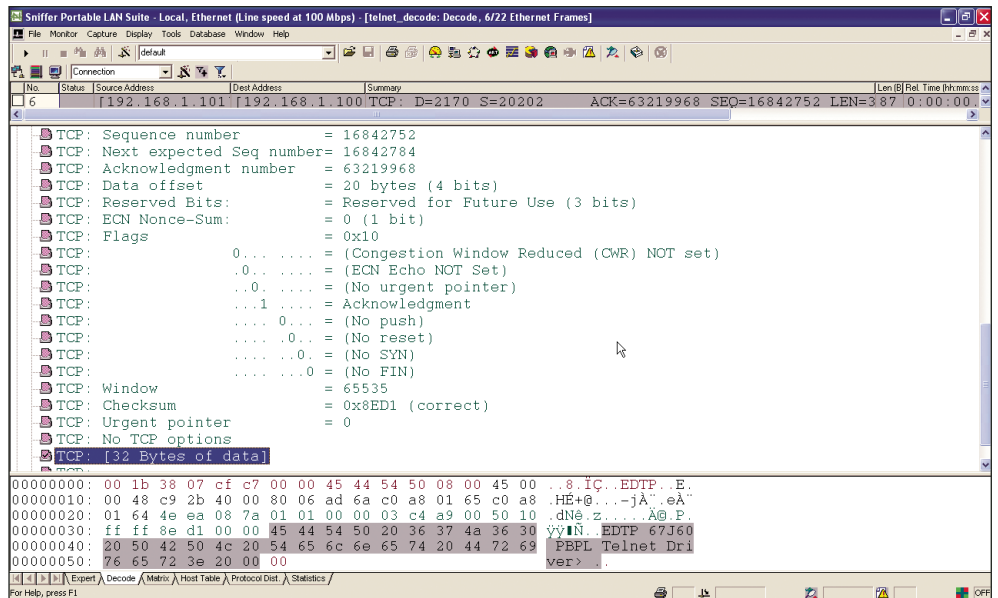
PawPaw and Bubba always acknowledged each other's message. Thus, we must do the same. In Sniffershot 2, the Ethernet MINI server is sending a TCP packet to the laptop client. Note that our Acknowledgement number is the laptop client's sequence number plus one for the SYN flag pseudo byte. We have successfully acknowledged (ACKed) the receipt of the SYN from the laptop client. It's not enough for the Ethernet MINI to simply keep up with the client's sequence number. The laptop must also keep a running tally of the bytes coming in and going out. So, the EDTP MINI sends along its initial sequence number to the laptop and sets the ACK and SYN flags in the outgoing packet. This is the second part of the three-way handshake process.

We are now in position to perform the final handshake. Here's what should happen:

- 1) The client laptop should ACK the EDTP Ethernet MINI's SYN.
- 2) The incoming packet received by the MINI has the ACK flag set.

Sniffershot 3 fills in the blanks.

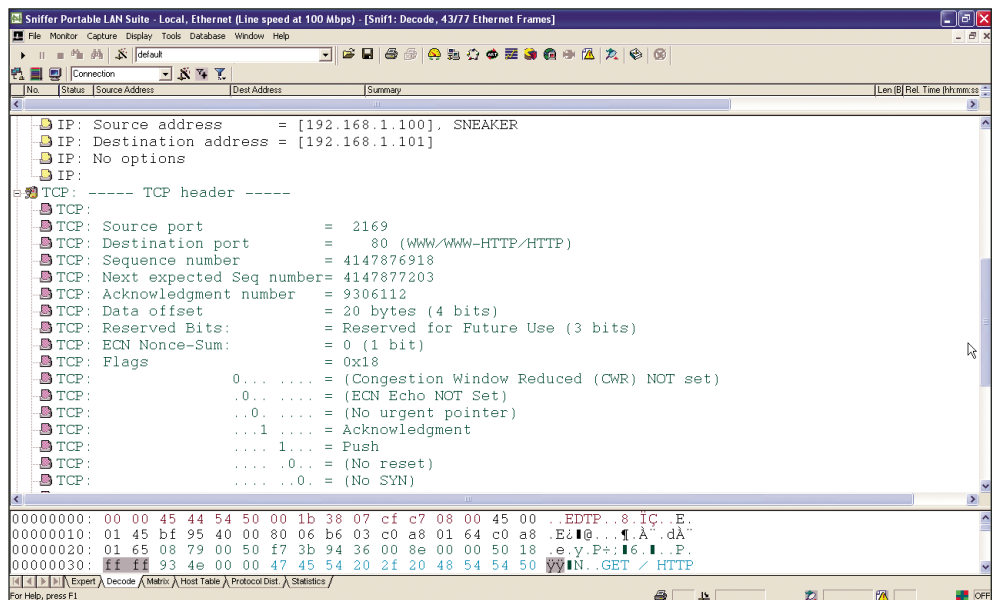
■ **SNIFFERSHOT 5.** The ACK and PSH flags along with the GET command set this capture apart from a normal TCP packet. Note that the Sniffer Portable application has recognized port 80 as a well-known HTTP port.

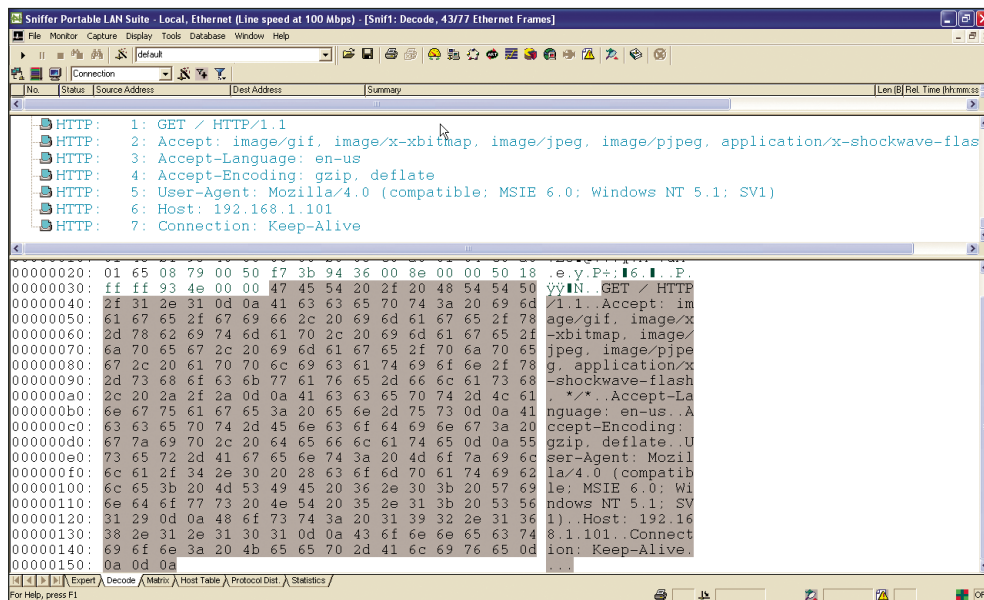


The Acknowledgement number received by the EDTP Ethernet MINI has incremented by one indicating the SYN ACK packet was received and has been acknowledged by the laptop. As no data was included in the incoming handshake reply, the Sequence number does not change. The third handshake is signaled by the setting of the ACK flag in the MINI server's incoming handshake response. All of the required numbers have been exchanged. It's time to haul some data.

A BANNER DAY

A bit of simple math used against the Sequence number and Next expected Seq number tells us that 32 bytes of data flowed from the Ethernet MINI server to the client laptop in the TCP packet represented in Sniffershot 4. The ACK flag will always be set from now on indicating that the Acknowledgement number is being actively tracked. The work performed in Sniffershot 4 transmitted the EDTP





■ **SNIFFERSHOT 6.** Out of all of the data, all we really want are the first five characters.

The telnet_banner label is an address place holder for the ASCII data that follows the Microchip PIC Assembler directive da, which stands for Data ASCII. The da directive generates a packed 14 bit number that represents a pair of seven-bit ASCII characters. The packed 14 bit numbers are stored in the PIC's program Flash. The packed strings are delineated with a trailing zero. The GetAddress macro is very simple and does not require elaboration. However, if the CHK?RP statement gives you gas, it's a PICBASIC PRO internal macro that looks up the register bank of the variable Wout.

Ethernet MINI's Telnet banner message (EDTP 67J60 PBPL Telnet Driver>) to the client laptop's Telnet application.

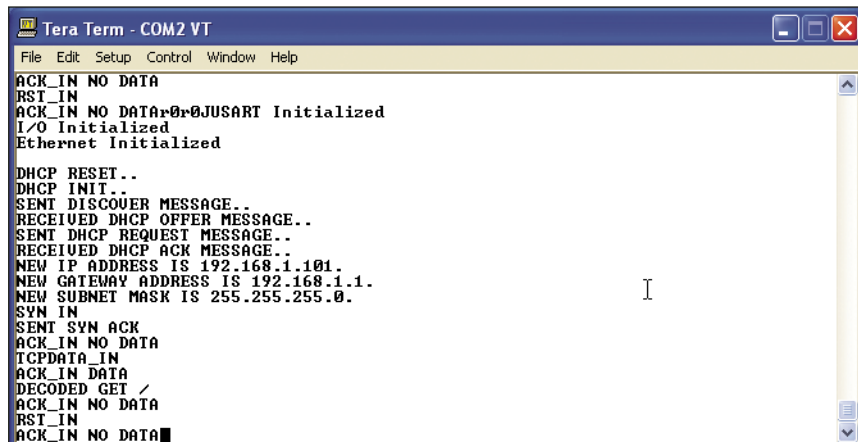
The results of the transmission can be seen in Screenshot 1, which is a shot of the laptop's Telnet application window. You can easily see that the Ethernet MINI's application is working as characters entered into the laptop's Telnet application were echoed by the EDTP Telnet application.

I used a bit of Darrel Taylor's magic to get the EDTP Ethernet MINI's Telnet banner on a wire. Rather than embedding the Telnet banner message in an array, I used some tricky DT code to store the Telnet banner message in the PIC's program Flash. Check this out:

```
telnet_banner:
@ da "EDTP 67J60 PBPL Telnet Driver> ",0
'-----GetAddress Macro - Location insensitive -----
ASM
GetAddress macro Label, Wout      ; Returns the Address
                                   ; of a Label as a Word
    CHK?RP Wout
    movlw low Label
    movwf Wout
    movlw High Label
    movwf Wout + 1
    endm
ENDASM
```

As you go through the PICBASIC PRO EDTP Ethernet MINI driver source code, you'll see that I did not convert all of my strings-handled-by-array routines to the neat little GetAddress macro. If your application is memory constrained, I suggest making the change in your code as the macro method of string handling uses less memory. As far as string handling goes, I've only shown you the tip of the iceberg. There are lots of posts on embedding strings in program memory in the PICBASIC PRO forum. Here is a snippet of code from the MINI TCP driver module that applies the GetAddress macro:

```
i_tcp      var word
tcpdatalen_out  var word
flashaddr    var word
flashchar    var byte
;send the Telnet server banner
;limit the Telnet banner
; character count to 40 decimal
@ GetAddress _telnet_banner, _flashaddr
i_tcp = 0
tcpdatalen_out = 0
repeat
    Readcode flashaddr, flashchar
    packet[TCP_data+i_tcp] = flashchar
    i_tcp = i_tcp + 1
    tcpdatalen_out = tcpdatalen_out + 1
    flashaddr = flashaddr + 1
until flashchar = 0
```



Using the GetAddress macro solved some other problems, as well. I was able to ignore precalculating the length of the Telnet banner message as it is automatically calculated with the variable tcpdatalen_out, which is ultimately used in the transmission of the Telnet banner message.

As naval aviators say, "Splash 1." Let's move on and target the next boogie, HTTP.

■ **SCREENSHOT 2.** Now you know why I included a serial port in the EDTP Ethernet MINI hardware design. I used the PICBASIC PRO hserout command instead of breakpoints while debugging the Ethernet MINITCP driver code.

■ **SCREENSHOT 3.** Now you know what is behind these five simple words.

A MINI WEB SERVER DRIVER

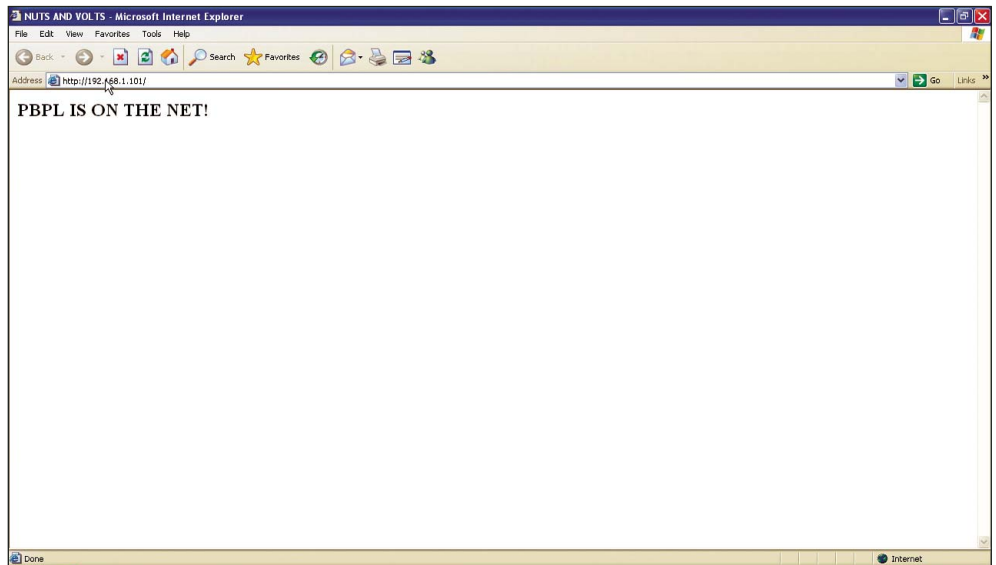
I'll begin our HTTP conversation by stating that you can make web serving as complicated as you desire. I'm not going to get complicated here. However, I will show you how to code the basic HTTP routines. If you haven't downloaded the new TCP-HTTP enabled PICBASIC PRO source code from the *Nuts & Volts* website (www.nutsvolts.com), please do so now. Note that the TCP code module is divided by the incoming port address. The Telnet driver we just examined via Sniffer Portable screen captures is almost identical to the HTTP driver module. When an incoming TCP packet is addressed to port 20202, the TCP driver will divert to the MY_PORT_ADDRESS TCP code, which handles the Telnet application. If the incoming destination port is 80, the EDTP Ethernet MINI's TCP driver module will branch to the WEB_SVR_ADDRESS code. Otherwise, all of the ARP, DHCP, and TCP stuff we've discussed thus far still figures into getting a web page served from the MINI.

As you already know, the acquisition of a web page from a server normally begins with a URL (Uniform Resource Locator) entered into the address field of a web browser. You can also get the contents of a web page in raw format from a Telnet session by opening port 80 of the desired server. Try opening a Telnet session to your EDTP Ethernet MINI and instead of specifying port 20202, specify port 80. You won't get a fancy banner like the one we coded. Just enter in "GET /" and the Ethernet MINI will return the raw HTML code to the Telnet window. The "GET /" command is basically what a web browser spits out when it wants to retrieve a page of HTML from a server. Consider Sniffershot 5.

Sniffershot 5 is a capture of the laptop's web browser issuing the GET command to the MINI server. At this point, the three-way handshake has been completed and a session is up between the laptop's web browser and the EDTP Ethernet MINI's TCP driver module. The Destination port value of 80 causes the MINI TCP driver code to execute the HTTP code area of the TCP driver module. Note that the Acknowledgement and Push flag bits are set. Otherwise, Sniffershot 5 looks like any other TCP capture.

The EDTP Ethernet MINI's TCP-HTTP driver is looking for the "GET /" command within the data area of the incoming HTTP request packet. As you can see in Sniffershot 6, there are plenty of other data items we could key on, as well. However, we are keeping it simple and will only act on the presence of a "GET /" command within the TCP packet data area.

I've again used the EDTP Ethernet MINI's serial port to track the progress of the MINI driver code, just as we did with



the DHCP module build-up. Take a look at Screenshot 2. All of the hardware initialization leads to the DHCP sequence, which assigns the MINI an IP address. SYN IN signals the first TCP session handshake which, in this case, is initiated by the laptop's web browser. The EDTP Ethernet MINI responds with the second portion of the three-way handshake, a SYN-ACK response. The laptop completes the handshake process by replying with an ACK packet that does not contain any data. At this point, the TCP session between the laptop and the MINI is up.

All of the events that follow the establishment of the TCP session are aimed at retrieving some HTML from the EDTP Ethernet MINI, which is about to be put into web server mode. TCPDATA_IN is sent to the Tera Term Pro terminal emulator window in response to an incoming TCP packet that contains data. If the destination port is 80 and the ACK and PSH flags are set, the code that follows is invoked:

```

; if an ack is received and the port address is valid
; and there is data in the incoming packet
  if((packet[TCP_hdrflags+1] & ACK_IN) &&_
    (packet[TCP_hdrflags+1] & PSH_IN) &&_
    (tcpdatalen_in)) then
    hserout[13,10,"ACK_IN DATA"]
    temp = 5
    i_http = 0
    while temp
      http_temp[i_http] = packet[TCP_data+i_http]
      i_http = i_http + 1
      temp = temp - 1
    wend
    if((http_temp[0] == "G") &&_
      (http_temp[1] == "E") &&_
      (http_temp[2] == "T") &&_
      (http_temp[3] == "$20") &&_
      (http_temp[4] == "/" )) then
      hserout[13,10,"DECODED GET /"]
@  GetAddress _http_ok_msg, _flashaddr
  i_http = 0
  tcpdatalen_out = 0
  repeat
    Readcode flashaddr, flashchar
    packet[TCP_data+i_http] = flashchar
    i_http = i_http + 1
    tcpdatalen_out = tcpdatalen_out + 1
    flashaddr = flashaddr + 1
  until flashchar = 0
  bhttpflag = 1
  bfinflag = 1

```

The first five characters of the incoming TCP data are read. If the "GET /" command is present in these five data bytes, the Ethernet MINI TCP driver pushes "DECODED GET /" out of the MINI serial port and prepares to transmit the HTTP OK message, which looks like this:

http_ok_msg:

```
@ da "HTTP/1.1 200 OK \r\n Content-Type:
text/html\r\n\r\n<html><head><title> NUTS AND
VOLTS </title></head><body><b><H2>PBPL IS ON THE
NET!</H2></b></body></html>";0
```

The OK response also includes some choice HTML that results in what you see in Screenshot 3. The OK message includes HTML for the web page title (NUTS AND VOLTS), as well as some text for the web page body (PBPL IS ON THE NET!). Naturally, you can embed any HTML message you desire.

Looking back at Screenshot 2, the web browser acknowledged the HTML bytes it received (ACK_IN NO DATA). At this point, the web browser has no more use for the MINI web server as it has its requested page of HTML. So, the web browser application issues a reset in response to the FIN flag that the EDTP Ethernet MINI sent along with the HTML packet. If the web browser requires another page from the Ethernet MINI, it will establish a new TCP session and repeat the process we've just walked through.

SPLASH 2

There it is. All of it. Now you have total control of the major Internet protocols by way of the EDTP Ethernet MINI and its PICBASIC PRO driver.

Design Cycle is intended to spur your thought processes and provide a basis for personal projects. A Design Cycle reader named Tom Matthews recognized that fact and took it upon himself to fashion his own version of PICBASIC PRO TCP driver code. Congratulations, Tom! I hope to hear many more stories like yours. Put another notch in your soldering iron as you can now add TCP and HTTP functionality to your Design Cycle. **NV**

SOURCES

■ **microEngineering Labs**
(www.melabs.com)
PICBASIC PRO

■ **EDTP Electronics, Inc.**
(www.edtp.com)
EDTP Ethernet MINI

■ **Bugtussle Hollar** Fayetteville,
TN Moonshine

■ **Network General**
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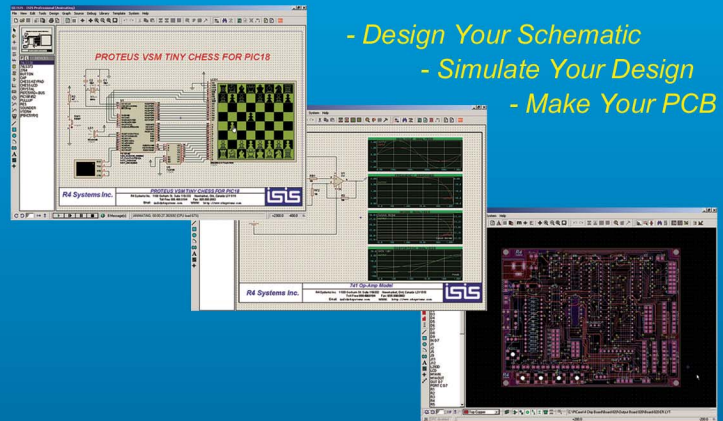


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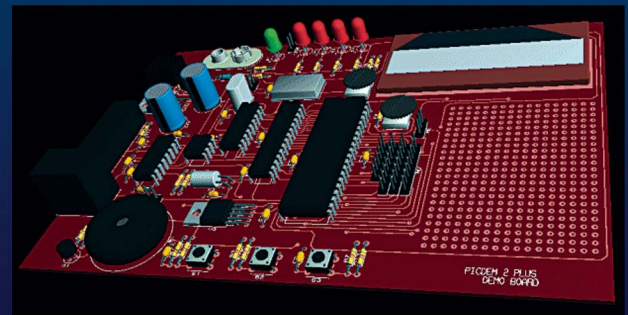
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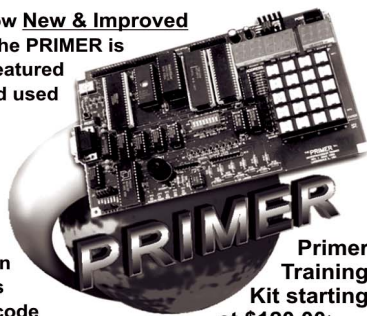
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A PALLET OF TALENT

I'm lucky in many ways but especially in that I am surrounded by creative, helpful, and talented folks (let's leave crazy out of it, for now!) In order to bring this project to completion, I would need all the help I could get. It was time to draw on the "Pallet of Talent" that surrounds me.

As most of the members of The Robot Group are full-time occupied with work, school, or parenting, 30 days is not much time for a project of this scope. It never ceases to amaze me that no matter how simple a project appears when sketched on paper, it becomes increasingly complicated on the journey to reality! I firmly believe the truism that "inside every little problem is a great big problem waiting to jump out."

Conversely, it's astonishing how a complicated or difficult project can bring out the best in people while many times uncovering their otherwise hidden talents. I also find it fascinating that I learn SO MUCH simply by making something. For example, did you know that ping pong balls come in two diameters (38 mm "hobby" and 40 mm "professional")?

Most of my projects progress from sketches to "To Do" or "parts" lists, so I began to enumerate all the things I would need. I then posted the listing to our group's mailing list (our mailing list is archived on our website if you want to see all the gory details). Almost immediately I started receiving phone calls and emails from folks saying they could do this part or that part, and we started to schedule times and tasks. In a matter of hours, I had already received an updated version of my sketches done in a CAD program from one of our members (Figure 2). The process had begun.

THE MACHINE THAT GOES PING!

A wide variety of people brought their various disciplines to bear in the creation of the Ponginator. I started out collecting various sirens, Klaxons, and alert sounds, and editing together the "soundtrack" that would alert the crowd to the Ponginator's activities. I

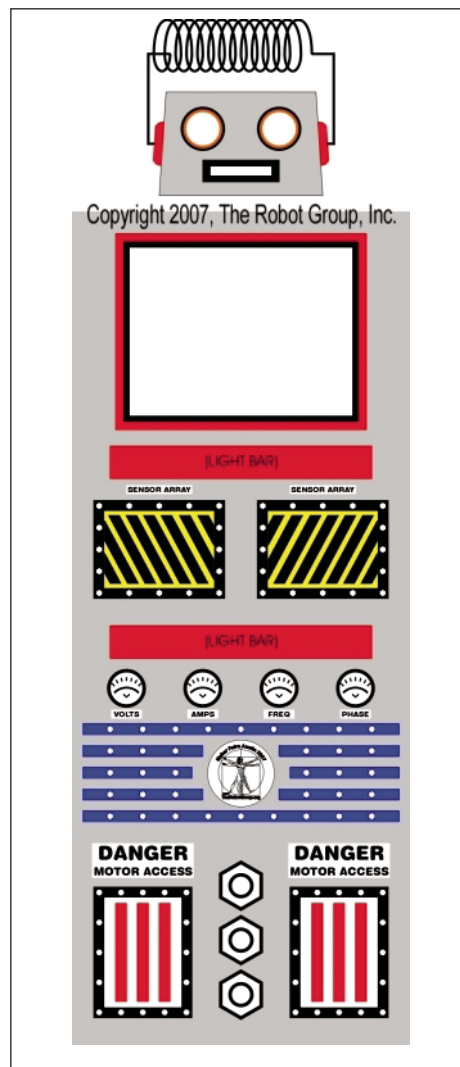
■ FIGURE 2. Ed's CAD drawings.

then edited various songs to match the length of — and play behind — the sound effects to help build excitement as the robot fired its guns. With about all the desk-based work complete, it was time to start gathering all the major pieces for the Ponginator and evict my car from the garage for another project.

We started by getting two full frames of scaffolding and a large silver-colored construction tarp. We put one layer of scaffolding up in the garage so we could test the gun movement. We then created two gun turrets from 3/4" plywood and used an eight foot 2 x 12 for the "shoulders." Using some L brackets, we hung the two gun turrets and mounted heavy-duty surplus gear head motors to raise/lower the guns.

The motors were originally designed to position satellite dishes so they have lots of torque. So much torque in fact, we ended up using custom machined motor mounts for them as our first torque tests threatened to rip the wood screws free from the plywood! With the motor mounts, we could use bolts and fender washers to firmly attach the motors to the turrets (Figure 3).

The next step was to create the ping pong ball guns themselves. We pondered a number of designs, experimenting with rubber "surgical" tubes that would shoot the balls like a sling-shot and one of our members even fab-



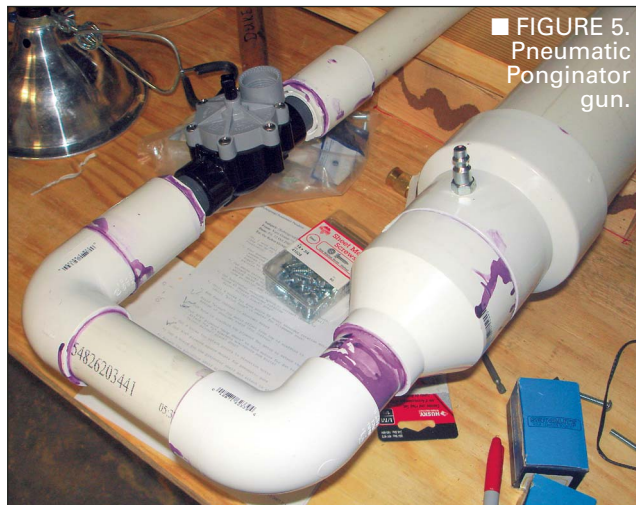
ricated a mechanical system that used counter rotating wheels to "throw" the



■ FIGURE 3. Gun turret with motor mount.



■ FIGURE 4. Rick's first shooter.



■ FIGURE 5. Pneumatic Ponginator gun.



■ FIGURE 6. The author loading the guns.

balls like a pitching machine (Figure 4).

We had hoped to make the system auto-loading with some type of hopper to hold the ammo. We sketched up and experimented with numerous different designs with the first requirement being throwing distance (we wanted to be able to hit the middle, if not the end of the arena!) and the second biggest concern being reliability. We had to consider that the end product would be suspended 15 to 20 feet in the air, so it would be difficult (if not down right dangerous) to reach it for diagnostics, adjustment, or repair.

In the end, we settled on a simple design based on one of many pneumatic spud gun plans we found on the Internet. Our final gun consisted of a length of 4" ID PVC pipe configured as an air reservoir, an inexpensive 1" sprinkler valve as a trigger, and a piece of 1.5" PVC pipe as a barrel (Figure 5).

Due to concerns with reliability and the short time we had to build

things, we settled on a "muzzle loaded" design using strips of a plastic drinking cup to hold the ping pong ball in place after loading. Because the gun turrets would rotate, we were able to point them down for loading, and then point them almost straight up in order to allow the balls to settle into position for firing (Figure 6).

We wanted the balls to be memorable, so we found a shop that could print our logo onto the ball (Figure 7). We ordered four gross of logo-embazoned ping pong balls. They were scheduled to arrive just two days before the Faire! In the meantime, we did our testing with some ping pong balls purchased at local sports shops.

FIRST "BUMP" IN THE ROAD

Once we had four pneumatic guns built and tested, it was time to test the

shoulder pan motion. The original design called for the 2 x 12 cross plank to rotate to allow the head and shoulders to pan the guns across the arena. This would allow us to shoot ping pong balls both into the arena and also up into the stands. The pan cross plank was designed with outrigger wheels that would carry the weight of the guns so the motor would only have to provide the rotational torque to move the shoulders (Figure 8).

When we got all four guns hung on the turrets, and applied power to the 12V pan motor using a 12V gel cell, the motor made a soft click and did not move the shoulders at all! We removed the guns and the shoulders would pan with ease. Turns out that with the guns mounted, the assembly was just too heavy for the motor to get moving.

We didn't have time to redesign the shoulders or replace the motor, so I decided to see if a bit more "juice" might make the motor turn. I grabbed a second gel cell and put it in series to get 24V. Again, the motor went click but a bit louder this time. I picked up another gel cell, added it for 36V, and the motor started to barely move, but after a short slow turn, it got stuck. I tried reversing it, but no luck. It stayed put.

Having another gel cell handy, I added it in series as well, and hit that motor with 48V! The shoulders creaked and lurched into action and the shoulders began to pan! Success!

But then, a very loud crackling sound came from the motor's gearbox and the shoulders ground to a halt. Turns out 48V is enough to get the motor turning, but the gear train wasn't up to the task and disintegrated into metal shards! Lucky for us, it hadn't frozen up so we were able to manually position the shoulders point-



■ FIGURE 7. Ponginator ammo.



■ FIGURE 8. Shoulder rotation cross plank.

ing in a single direction for the show and put the shoulder rotation plans on the back burner for now. We built Ponginator's head from a large plastic storage bin (Figure 9); mounted some boat navigation lights for antennas; some push lights were modified with servos and high brightness LEDs for eyes; some decorative lightning lights were added as ears; and a sound activated CCFL light bar in a box was placed behind a metal screen to act as a mouth. As I knew the controls would all be at ground level but the things being controlled would all be up high, I used RJ-45 jacks on both the motor/head end and also at the control board end. This made it easy to find cables of the proper length to use for the finished project as we could use standard Ethernet cables.

■ FIGURE 9. Ponginator's head.



WE HAVE ASSUMED CONTROL ...

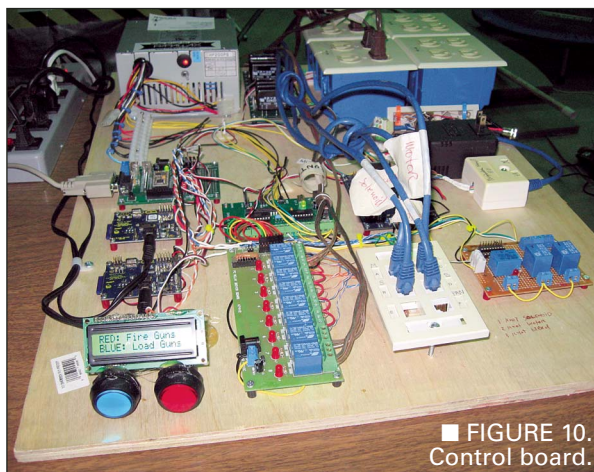
Now that we had gun turret motors and solenoid operated sprinkler valves, I had to have something to coordinate all this machinery. I cut a sheet of 1/2" plywood to about 2' x 3' and then started to gather and attach the microcontroller components I figured I would need to control the show (Figure 10). I ended up using:

- Parallax BASIC Stamp IIP24
- Parallax Super Carrier Board
- Parallax Serial LCD display
- Solutions Cubed Motor Mind C
- Solutions Cubed Motor Mind C Carrier Board
- EFX-TEK RC4 (quantity two)
- EFX-TEK DC-16
- Circuit Specialists Kit 74 octal relay control board
- Rogue Robotics uMP3 sound players (quantity two)
- Surplus 250W ATX PC power supply

With the control board built, we

had the last piece of the puzzle, so it was time to load it all up and truck it about 15 miles to the arena. I borrowed a large truck and trailer from my brother (thanks Walt!) and we loaded the Ponginator and all the other displays for the Faire onto the trailer. (Oh, did I forget to mention that in addition to creating the Ponginator in 30 days, we also had about a dozen other Robot Group created displays we had to set up for the Faire — see Resources. We were a very busy crew.)

Once we arrived on site, we had to assemble the Ponginator for the first time (Figure 11). We had put up one layer of scaffolding in my garage



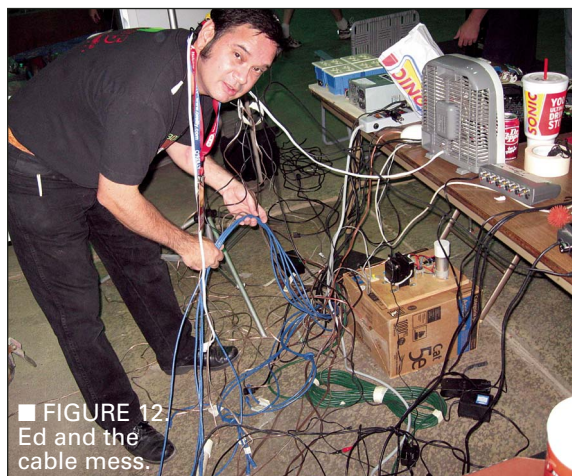
■ FIGURE 10. Control board.

READY ... AIM ... PING! (The Ponginator Firing Sequence)

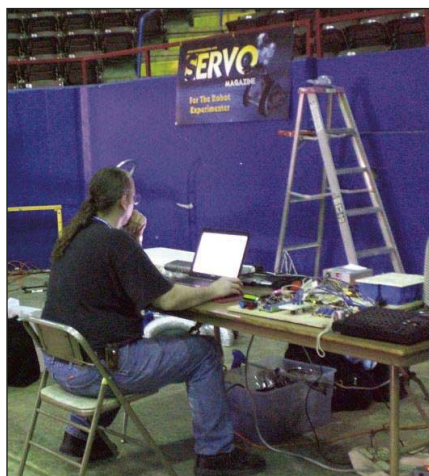
- Press the fire button.
- Parallax BSIIp starts countdown on LCD.
- EFX-TEK DC-16 activates smoke machines.
- First uMP3 player starts sound effects.
- S3 Motor Mind C moves gun turrets into firing position.
- EFX-TEK DC-16 blinks LED eyes, antennas, and mouth.
- EFX-TEK RC4 blinks rope Lights and activates police light bar.
- Second uMP3 player starts background music.
 - EFX-TEK DC-16 fires solenoid valve.
 - Parallax BSIIp pauses 10 seconds.
 - S3 Motor Mind C moves gun turrets to new position.
- Repeat above three actions for next three shots.
- First uMP3 fades out sound effects.
- Second uMP3 fades out music.
- EFX-TEK RC4 and DC16 turn lights out.
- S3 Motor Mind C moves gun turrets into load position.
- Manually muzzle-load the guns for next shot.
- Press button, guns raise to seat ping pong ball ammo.
- Ready to fire



■ FIGURE 11. Trailer unloading.



■ FIGURE 12:
Ed and the
cable mess.



■ FIGURE 13. Author writing Ponginator code

about four hours till the Faire was going to pre-open for the press and I hadn't written the software that operated him yet.

CODE MONKEY LIKE FRITOS

The reason for the lack of code was pretty simple. I had not been able to write code for a device that didn't exist. Now that I had the device fully

in the week before the show, but we had never put all the pieces together at full height and with the "skin" fitted. We assembled the two stories of scaffolding, then wrapped the frame in the skin for the first time. We then cut the hole for the video screen, mounted the video projector, and hoisted the gun assembly into place.

We mounted the smoke machines and screwed the head down to the

cross bar, then ran the cables down to the control board (Figure 12). We added the lights and the lighting power lines, as well as the closed circuit video camera that would display a Ponginator's eye view of the crowd as the ping pong balls rained down.

It took us hours to get the Ponginator fully assembled, but when he was finally up and ready to go, there was really only one "little" problem. We had

assembled, I could finally begin to write and test the routines that would control the gun firing solenoids, activate the lights, LED eyes, and police lights, start and stop the music players, rotate the gun turrets, and turn on and off the smoke machines (Figure 13).

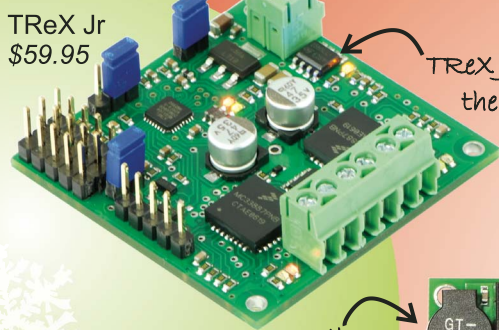
Luckily, I had used many of the controllers before so I had some code chunks from previous projects that I could cut and paste together to talk to

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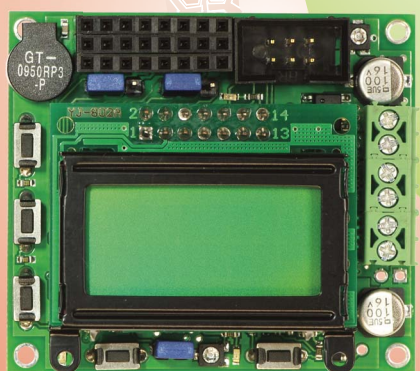
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PONGINATOR PALLET OF TALENT

Rick Abbott, Alberto Alonso, Paul Atkinson, Brooks Coleman, Bob Comer, David Comer, Tom Davidson, James Delaney, Wolf Dilworth, John Funk, Vern Graner, Kym Graner, Nic Graner, Sami Graner, Ed Xavier Gonzalez, John Herron, Nyssa Hughes, Puiyee Hung, Eric Lundquist, Gary Mack, Marvin Niebuhr, Sonia Santana, Denise Scioli, and Mike Scioli.

the LCD panel, the uMP3 music players, DC-16 controller, and so on. The final code was rather straightforward as it simply stepped through sequences with timed intervals separating events. The Ponginator firing process is described in detail in the sidebar "Ready Aim PING!".

CAN WE DO IT? YES WE CAN!

What could unite school teachers, plumbers, carpenters, laser technicians, entrepreneurs, software engineers, artists, musicians, photographers, stay-at-home moms, cube dwellers, electrical engineers, students, and kids? A project just like this. We were all

working towards a common goal. We knew the result could be wonderful, and it was. The Ponginator was a huge hit! It worked wonderfully, the crowd loved it, the kids loved it, and it drew people to our displays all weekend. It even made the local news cast (see Resources).

I created a short documentary video using photos and video clips collected during the creation of the Ponginator and also during his performance at the MAKER Faire (see sidebar). I encourage you to have a look and to see the type of project you can be a part of if your personal robotics interests are joined

with those of others in your home town.

The Ponginator is also a prime example of how the whole really can be greater than the sum of its parts. Some rough pencil sketches, old scaffolding, silver tarp, PVC pipe, sprinkler valves, a storage bin, and some electronics, when mixed with the right people, became a triumph that I don't think anyone involved will soon forget. **NV**

RESOURCES

■ The Robot Group entries for MAKER Faire:

- <http://makerfaire.com/austin/2007/tags/index.csp?tag=The%20Robot%20Group>
- <http://tinyurl.com/23x444>

■ Fox 7 News MAKER Faire Showcases Unique Inventions

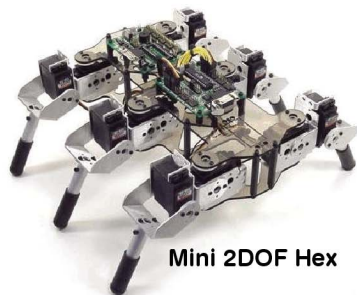
- www.myfoxaustin.com/myfox/pages/Home/Detail?contentId=4695465&version=1&locale=EN-US&layoutCode=VSTY&pageId=1.1.1
- <http://tinyurl.com/3aa23d>

■ Video of the Ponginator

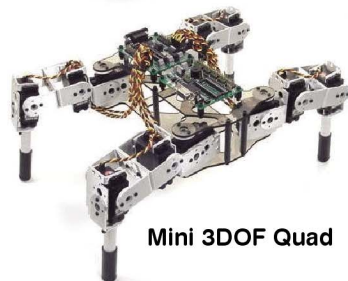
- www.youtube.com/watch?v=iPSoFYHywJw



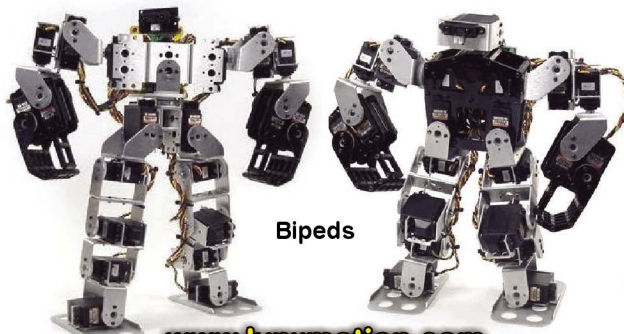
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Mini 2DOF Hex



Mini 3DOF Quad



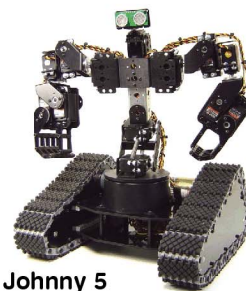
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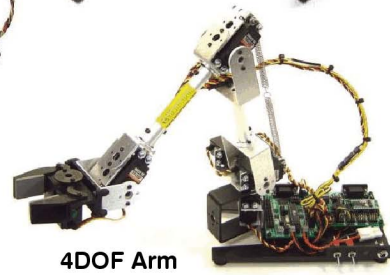
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STOCKING YOUR LAB

ONE OF THE MORE COMMON EMAILS I RECEIVE involves recommendations on which PIC® microcontroller (MCU) should be stocked in the home lab. Microchip offers so many choices that the beginner can become very confused as to which ones to have handy. Engineers also often wonder if the choice of compiler matters, and then they get into questions about the best programmer, development boards, etc., to use. This month, I thought I would cover a topic I addressed before, but since many people have not read all my articles, I thought I would cover my choices for the best microcontrollers to stock in your home lab.

Your choice of compiler won't matter much, unless you want to use one of the free sample or student versions. Even then, there might be only certain parts that the compiler supports. Microchip provides both eight- and 16-bit microcontrollers, as well as 16-bit Digital Signal Controllers (DSCs). In this column so far, we've focused on the

eight-bit devices, so I'll continue that discussion here.

In Microchip's eight-bit family are the PIC10F, PIC12F, PIC16F, and PIC18F prefix parts. The PIC10F and PIC12F are the small, eight-pin DIP package parts. The PIC10F gets even smaller, down to six pins if you will work with surface mount. As most hobbyists still develop with DIP packages, I recommend the PIC12F683 for the small eight-pin package size. The features of the PIC12F683 are listed in Table 1.

The PIC12F683 is also supported by microEngineering Labs' PICBASIC PRO™ compiler so, if you can write your code in 31 Basic commands or less, this is great to get started with.

The PIC16F family is larger and

includes package sizes from 14 up to 64 pins. For the 14-pin package, I recommend you stock the PIC16F688. This is Microchip's largest memory, 14-pin package part and has all the features most of your projects will need. The features of the PIC16F688 are listed in Table 2.

The next step up in the PIC16F family is the 20-pin package, and the best choice in my mind is the PIC16F690. The PIC16F690 has many of the same features as the PIC16F688, but more I/O. This is also the part that comes with the Microchip PICKIT™ 2 Starter Kit that I've discussed in this column before. Both the PIC16F688 and PIC16F690 are supported by the PICBASIC PRO compiler. The PIC16F690 is also

supported by the HI-TECH PICC-lite C compiler that comes on the PICKIT 2 Starter Kit CD. I liked this setup so much that I based my book on the C programming language (book is still in the works) on this compiler and this PIC MCU. The PIC16F690 features are listed in Table 3.

I jumped over the 18-pin parts because the eight-, 14-,

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TABLE 1: PIC12F683 Features

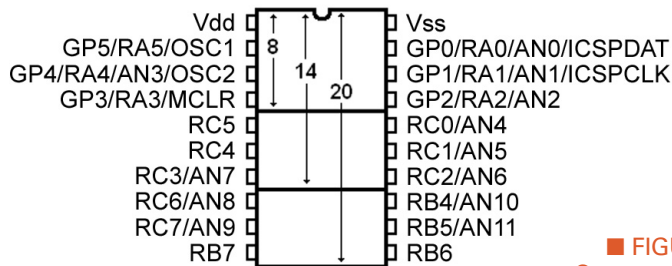
- 3.5 Kbytes/2 K-word Program Memory (14-bit address)
- 128 RAM
- Four 10-bit Analog-to-Digital Converters (ADCs)
- One Capture/Compare/Pulse Width Modulation (PWM) Peripheral
- One Comparator
- Three Timers
- Internal Oscillator up to 8 MHz
- 256 bytes of EEPROM



TABLE 2: PIC16F688 Features

- 7 Kbytes/4 K-word Program Memory (14-bit address)
- 256 RAM
- USART
- Eight 10-bit ADCs
- Two Timers
- Two Comparators
- Internal Oscillator up to 8 MHz
- 256 bytes of EEPROM





■ FIGURE 1.
Common Pins.

and 20-pin parts share a common pin-out structure for the top eight pins, so they can also share a development board. Figure 1 shows the structure of the common pins.

My recommendation for the 18-pin package is the PIC16F88, though I find I'm now using the PIC16F690 more often. The only thing you give up with this device is some RAM. If you have a program that requires quite a bit of variable space, then the 368 bytes of RAM in the PIC16F88 vs. the 256 bytes in the PIC16F690 can make a difference. The PIC16F88 also supports self-write memory, so you can program it via a serial port bootloader. This can be a nice feature.

The 28- and 40-pin packages have long been my most favorite parts to develop with. In the past, I've always used the PIC16F876A (28-pin package) and PIC16F877A (40-pin package) devices, as they have all the features and I/O I typically need, plus they provide more memory space. In fact, these have the largest memory space available in the PIC16F family. These parts are also supported by the sample version of PICBASIC PRO, and the PIC16F877A is supported by many other compiler sample versions.

I still recommend you keep some of these devices in your lab, but an upgrade to the family was recently released, and my two recommendations are the PIC16F886 (28-pin package) and the PIC16F887 (40-pin package). They add a few more features the PIC16F87XA parts don't offer.

The biggest advantage is the internal oscillator. The PIC16F87xA parts require an external oscillator, but if all you need is a speed of 8 MHz or

less, then the PIC16F88X parts have the same internal oscillator that the other parts I recommend have. So, I also recommend these parts for your lab.

THE PIC18F FAMILY

Some people want a lot of memory to start with, so they don't have to worry about running out of room. The PIC18F family fills this request nicely. It includes a lot of parts, many with unique features such as motor control peripherals and built-in USB. However, for the hobbyist just looking for additional memory, I recommend you stock the PIC18F2620 and PIC16F886 devices. The 28-pin PIC18F2620 has 32K words/64K bytes of program memory. This is four times the space that the PIC16F886 offers.

The other features are larger as well, including EEPROM and RAM. The nice part is that the PIC18F2620 is pin compatible with the PIC16F886, so when your PIC16F design runs out of memory, PIC18F part can plug right in.

You can get a PIC18F4620 with the same features as the PIC18F2620, plus three additional ADCs and more I/O, but in a 40-pin package that is pin compatible with the PIC16F887.

TABLE 3: PIC16F690 Features

- 7 Kbytes/4 K-word Program Memory (14-bit address)
- 256 RAM
- USART
- 12 10-bit ADCs
- Three Timers
- Two Comparators
- One Enhanced Capture/Compare/PWM (ECCP) Peripheral
- Internal Oscillator up to 8 MHz
- 256 bytes of EEPROM



TABLE 4: PIC16F88 Features

- 7 Kbytes/4 K-word Program Memory (14-bit address)
- 368 RAM
- USART
- Seven 10-bit ADCs
- Three Timers
- One Capture/Compare/PWM Peripheral
- Two Comparators
- Internal Oscillator up to 8 MHz
- 256 bytes of EEPROM
- Self-Write Memory



TABLE 5: PIC16F886 Features

- 14 Kbytes/8 K-word Program Memory (14-bit address)
- 368 RAM
- USART
- 11 10-bit ADCs
- Three Timers
- One Capture/Compare/PWM Peripheral
- One ECCP Peripheral
- Two Comparators
- 256 bytes of EEPROM
- Internal Oscillator up to 8 MHz
- Self-Write Memory

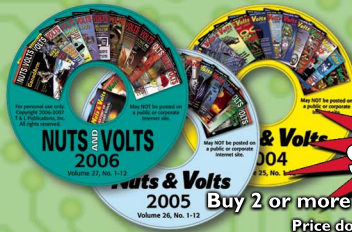


TABLE 6: PIC16F887 Features

- 14 Kbytes/8 K-word Program Memory (14-bit address)
- 368 RAM
- USART
- 14 10-bit ADCs
- Three Timers
- One Capture/Compare/PWM Peripheral
- One ECCP Peripheral
- Two Comparators
- 256 bytes of EEPROM
- Internal Oscillator up to 8 MHz
- Self-Write Memory



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TABLE 7: PIC18F2620 Features

- 32 Kbytes/64 K-word Program Memory (16-bit address)
- 3968 bytes RAM
- USART
- Ten 10-bit ADCs
- Four Timers
- Two Capture/Compare/PWM Peripherals
- Two Comparators
- 1,024 bytes of EEPROM
- Internal Oscillator up to 8 MHz



CONCLUSION

There are many choices for the beginner looking to stock his or her home lab, but the parts discussed in this article will get you started for 99% of your projects. As I mentioned, Microchip also has 16-bit microcontrollers and DSCs in the form of the PIC24 MCUs, and dsPIC30 and dsPIC33F DSCs. These devices offer even more memory, with some very high-level features. The only Basic compiler I know of for these higher-end parts is the mikroElektronika mikroB compiler, available at www.mikroe.com.

I use the PIC16F parts for 80% of my experiments, but I've been using the smaller packaged PIC12F parts a little more lately. These devices give me a ton of capability in one package that easily fits into a small project box. Even if you just got a few of each of the parts discussed in this article, you would have a great assortment in your home lab. You can order free samples at <http://sample.microchip.com>.

Please email me at with any questions or comments. Please also visit my website www.elproducts.com anytime, and I'll offer as much help as I can. **NV**

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■ Chuck Hellebuyck can be reached at chuck@elproducts.com

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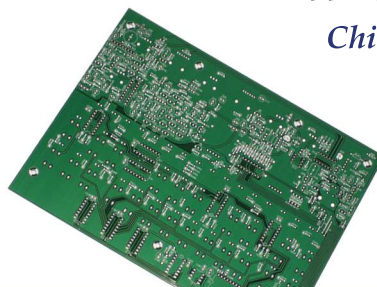
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READER FEEDBACK

Continued from page 8

SCOOP ON SCOPE

In the Q&A column, Russell, recommended a user remove grounding from a Tek T922 scope. This can be a tricky situation if the user places a hand on the scope frame at the same time he is touching ground.

There are two other ways to isolate the scope:

1) Use an isolation transformer. This floats the frame of the scope from ground without a casual return path.

2) The better choice (given the user can lay his hands on one) is to use a scope with differential vertical amplifier capability. Scopes with two vertical input channels often allow adding the two channels together and inverting one. The second channel would be attached to the ground of the device under test. Many older scopes have this capability with the use of plug-ins.

My two cents' worth.

Bill Roberts

Old time Tektronix employee

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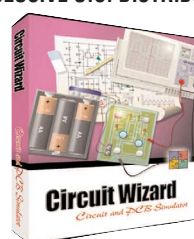
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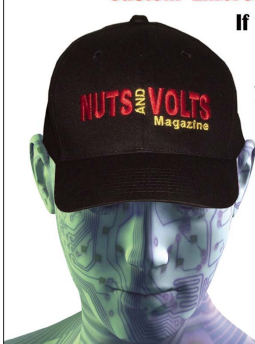
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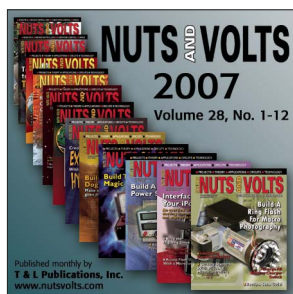
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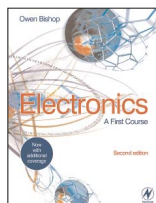
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ELECTRONICS

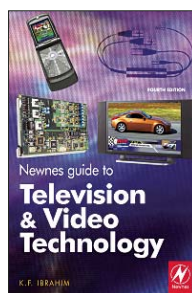
Electronics: A First Course Second Edition by Owen Bishop

Electronics: First Course starts with the basics of electricity and component types, and introduces students to practical work almost straightaway. No prior knowledge of electronics is assumed. The second edition now has additional applicability to BTEC First Electronics from Edexcel with coverage of fundamental topics required by students of this qualification, as well as other essential new topics that reflect recent technological developments. **\$34.95**



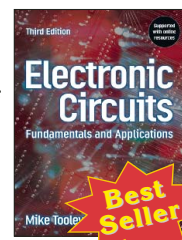
Newnes Guide to Television and Video Technology by K. F. Ibrahim

Starting with TV fundamentals, the bulk of the book covers the many new technologies that are bringing growth to the TV and video market, such as plasma and LCD, DLP (digital light processing), DVD, Blu-ray technology, Digital television, High Definition television (HDTV), and video projection systems. **\$34.95**



Electronic Circuits – Fundamentals & Applications: Third Edition by Mike Tooley

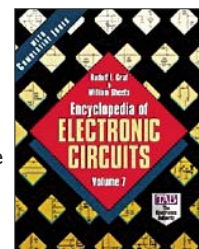
In *Electronic Circuits*, Mike Tooley provides all the essential information required to get to grips with the fundamentals of electronics, detailing the underpinning knowledge necessary to appreciate the operation of a wide range of electronic circuits, including amplifiers, logic circuits, power supplies, and oscillators. The third edition now offers an even more extensive range of topics, with extended coverage of practical areas such as circuit construction and fault finding, and new topics including circuit simulation, electronic CAD, and a brand new chapter devoted to the PIC microcontroller. **\$34.95**



Encyclopedia of Electronic Circuits, Volume 7

by Rudolf F. Graf / William Sheets
Publish Date: August 31, 1998

An extensive library of 1,000 circuits from the bestselling, seven-volume *Encyclopedia of Electronic Circuits*. A virtual treasurehouse. An invaluable reference tool for every hobbyist, technician, student, and design professional. **\$39.95**

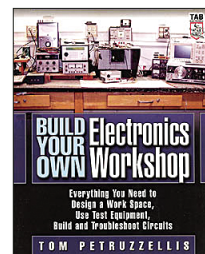


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By Thomas Petruzzellis

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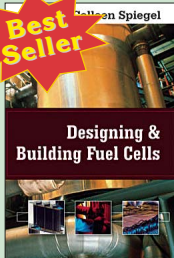


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Designing & Building Fuel Cells by Colleen Spiegel

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Designing & Building Fuel Cells equips you with a hands-on guide for the design, modeling, and construction of fuel cells that perform as well or better than some of the best fuel cells on the market today. Filled with over 120 illustrations and schematics of fuel cells and components, this "one-stop" guide covers fuel cell applications, fuels and the hydrogen economy, fuel cell chemistry, thermodynamics and electrochemistry, fuel cell modeling, materials, and system design, fuel types, delivery, processing, and much more. **\$89.95***



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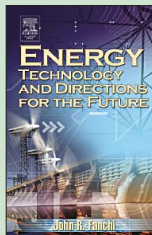


Going, Going, Gone Green!
 Check it out in our Webstore!
www.nutsvolts.com
\$24.95*

Energy Technology and Directions for the Future by John R. Fanchi

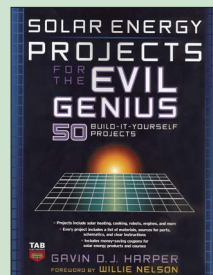
Publish Date: January 26, 2004

This book is a survey of energy sources that will be available for use in the 21st century energy mix. You will learn about the history and science of several energy sources, as well as the technology and social significance of energy. The book includes geothermal energy, fossil fuels, solar energy, nuclear energy, alternate energy and society, energy and the environment, sustainable development, the hydrogen economy, and energy forecasting. **72.95***



Solar Energy Projects for the Evil Genius by Gavin D. J. Harper

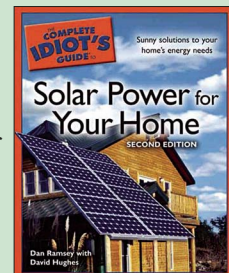
Let the sun shine on your evil side — and have a wicked amount of fun on your way to becoming a solar energy master! In *Solar Energy Projects for the Evil Genius*, high-tech guru Gavin Harper gives you everything you need to build more than 50 thrilling solar energy projects. You'll find complete, easy-to-follow plans, with clear diagrams and schematics, so you know exactly what's involved before you begin. **\$24.95**



The Complete Idiot's Guide to Solar Power for Your Home by Dan Ramsey / David Hughes

Publish Date: May 2007

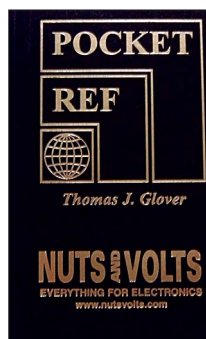
The perfect source for solar power — fully illustrated. This book helps readers understand the basics of solar power and other renewable energy sources, explore whether solar power makes sense for them, what their options are, and what's involved with installing various on- and off-grid systems. **\$18.95**



MUST HAVE

Pocket Ref by Thomas J. Glover

This great little book is a concise, all-purpose reference featuring hundreds of tables, maps, formulas, constants, and conversions. AND it still fits in your shirt pocket! Goes where you go! **\$12.95**



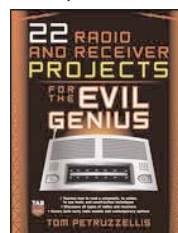
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22 Radio and Receiver Projects for the Evil Genius

by Thomas Petruzzellis

Publish Date: September 24, 2007

22 Radio and Receiver Projects for the Evil Genius features a unique collection of projects that teach you radio and electronics essentials such as the radio spectrum, how to read schematics, and how to solder. After each project is completed, you can enjoy listening to and using their new receiver. **\$24.95**



Solar Power in Building Design by Peter Gevorkian

Publish Date: September 23, 2007 *Solar Power in Building Design* is a complete guide to designing, implementing, and auditing energy-efficient, cost-effective solar power systems for residential, commercial, and industrial buildings. From basic theory through project planning, cost estimating, and manufacturing methods, this vital resource offers you everything needed for solar power design success. **\$99.95***

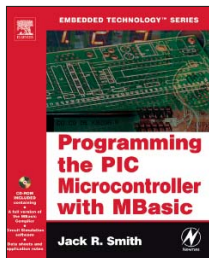


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MICROCONTROLLERS

Programming the PIC Microcontroller with MBASIC by Jack Smith

No microcontroller is of any use without software to make it perform useful functions. This comprehensive reference focuses on designing with Microchip's mid-range PIC line using MBASIC, a powerful but easy to learn programming language. It illustrates MBASIC's abilities through a series of design examples, beginning with simple PIC-based projects and proceeding through more advanced designs. **\$62.95***



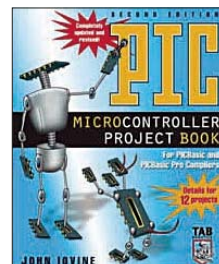
Programming and Customizing the PICAXE Microcontroller by David Lincoln

Here's everything you need to harness the power of PICAXE, the inexpensive yet versatile chip that's taken the electronics community by storm. This beginner-friendly guide from IT pro and PICAXE expert David Lincoln shows you just what Revolution Education's PICAXE can do — and helps you make it do it! Packed with ready-to-build projects for all the flavors of PICAXE. **\$39.95**



PIC Microcontroller Project Book by John Iovine

The PIC microcontroller is enormously popular both in the US and abroad. The electronics hobbyist market has become more sophisticated. This new edition is fully updated and revised to include detailed directions on using both versions of the microcontroller, with no-nonsense recommendations on which is better served in different situations. **\$29.95**



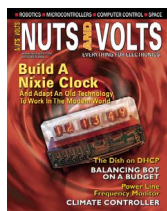
PROJECTS



Nixie Clock Kit



Custom Copper Box Not Included



As seen in the October 2006 issue



Nixie tube clocks fuse the spirit, drama, and eerie beauty of cold war technology with modern inner works to create uncommon handcrafted timepieces. This clock / kit was shown at the October 2007 MAKER Faire in Austin, TX by Nut & Volts Magazine and was very well received as a novel way to show the Nixie tubes. Plus, it's a great kit for all levels of electronic experience.

For more information, please check out your October 2006 issue or go to our website @ www.nutsvolts.com

Subscriber's Price **\$124.95** Non-Subscriber's Price **\$139.00** Both include an article reprint.

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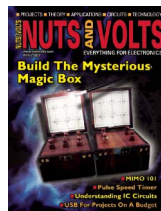
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Magic Box Kit

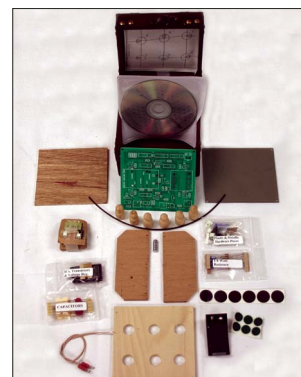


As seen in our April issue.

We received such great reviews on this magic box kit that we decided to offer it in our store.

This unique DIY construction project blends electronics technology with carefully planned craftsmanship. Its delightful innovation will surely amuse you. More importantly though, it bewilders, baffles, and mystifies those observing this subtle magic trick.

Subscriber's Price **\$39.95** Non-Subscriber's Price **\$45.95** Both include an article reprint.





TECH



FORUM

This is a READER-TO-READER Column.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and **NO GUARANTEES WHATSOEVER** are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams* should be computer generated and sent with your submission as an attachment.

QUESTIONS

To be considered, all questions should relate to one or more of the following:

- ① Circuit Design
- ② Electronic Theory
- ③ Problem Solving
- ④ Other Similar Topics

■ Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).

■ Include your Name, Address, Phone Number, and email. Only your Name, City, and State will be published with the question, but we may need to contact you.

■ No questions will be accepted that offer equipment for sale or equipment wanted to buy.

■ Selected questions will be printed one time on a space available basis.

■ Questions are subject to editing.

ANSWERS

■ Include in the subject line of your email, the question number that appears directly below the question you are responding to.

■ Payment of \$25.00 will be sent if your answer is printed. Be sure to include your mailing address or we cannot send payment.

■ Only your Name, City, and State, will be printed, unless you say otherwise. If you want your email address included, indicate to that effect.

■ Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

>>> QUESTIONS

I have noticed that many of the leads on capacitors and LEDs are magnetic, as are the bodies of carbon-film resistors (but not the leads). Why is that? Why not copper wire? Why is there iron in a carbon film resistor?

#12071

Richard Gagnon
St. Paul, MN

I subscribe to cable phone with a company that provides a bundle of high-speed Internet access, television, and phone service. A cable problem can cause any one or all three to crash. My primary concern is about the phone. When it goes out, you won't know it until you try to use it and get no dial tone, or if someone tells you later that they could not reach you. This has caused me to miss important calls and deliveries. Is there a circuit I could build to monitor the cable phone line and alert me (e.g., beep, buzz, blinking light, etc.) when it goes down? My provider hasn't a clue, and only apologizes for the inconvenience over and over again.

#12072

T. Campbell
via email

We have several computerized machine tools that use serial ports to upload and download their programs. It is getting harder and harder to have our minifile equipment repaired. I would like to use a USB Flash to upload and

download programs through the serial ports. It would be nice to have an LCD readout to choose what program to download from the Flash. Any help with this project would be appreciated.

#12073

Brent Lamb
Lubbock, TX

How do they generate that little yellow first down marker during TV football games? I know it's computer generated, but it's been driving me nuts as to how they do this! I can't figure it out!

#12074

Dwight Johnson
via email

I need a device (preferably off-the-shelf) with two serial ports that can capture a line of RS-232 data at 1200 or 2400 baud and then reorder the information sequence (user definable) and resend it on demand at 1200 or 2400 baud to a PC. The purpose is to convert data from a PBX to a form the PC can recognize; the program the PC is running cannot be adjusted to read the original data. I have looked at various single board microcontrollers, but most seem to be designed for 9600 baud, if they have a serial port.

#12075

Chris Snyder
Cosby, TN

I have a GPS unit made by Falcom in Europe. It is hidden in my vehicle and can be tracked on a private website for

a fixed dollar amount each month. I want to be able to track it from my home PC. Any ideas what software I will need and who sells it for my unit? I understand that each GPS has its own identification number so only it will respond to any query.

#12076

**Roy Kneale
Covina, CA**

>>> ANSWERS

[#09072 - September 2007]

I'm looking for a schematic for a low power wireless switch. Something simple, using transistors, with a range of 25-50 feet. Both the transmitter and receiver should be battery powered and act as a simple switch.

#1 You can find a schematic for a low power wireless remote control switch (maximum distance of 300 feet using ideal antennas) in an article by Anthony Caristi, entitled, "Build a 418 MHz Wireless Remote Control," in the April 2002 issue of *Nuts & Volts*. It provides for a battery powered receiver and transmitter, as well as AC.

However, it does have digital circuitry. I think with adjustments you can limit the range to 25-50 feet.

**William Ferlanti
New York, NY**

#2 A radio operated switch is readily available at hardware outlets such as Lowe's or Home Depot as wireless doorbells. Carlton model RC5110 is battery operated in both the transmitter and receiver. They are easily adapted to remote switching. Net search shows the price as \$29.95.

The receiver has a removable speaker driver that can be replaced to drive a transistor for whatever. They are multichannel units, so that several can be used in the same location. Three such have been working in my house for several years now.

Transmitter batteries last nearly a year when pulsed 40 to 50 times per day. Four AA NiMH cells in the receiver last three to four months even with an LED indicator for OFF/ON (about 1 mA). The range is more like 60 to 100 ft.

**Jack W. Glover
Winter Haven, FL**

[#09073 - September 2007]

Our club was vandalized several times in the last month. I need to put a video camera at the entry way and turn on a video recorder using a motion detector to record anyone who enters. A commercial motion detector security camera with a 12 minute digital video recorder made to look like a clock is available, but costs \$180.

Does anyone make a cheap digital recorder (recording on an SD or similar card) that I can trip using a standard motion detector and which can turn off when the motion detector sees no more movement? I can use a pinhole or similar camera as the video feed so the video source is not a problem. Battery operation of the recorder would be a plus.

#1 Your questions seem to imply that the camera you were trying at \$180 was expensive. Most people do not comprehend the cost of good video equipment. In any event, I have found a solution for persons who need something portable, battery operated, and self-contained. It is called the, "Recluse" and is considered a "stealth cam." In a single plastic container it houses a color camera, digital video recorder (which will record on motion), battery, and SD memory card. It has inputs and outputs and can be run by the re-charging transformer that comes with it. It comes in a nicely packaged kit with an SD/USB converter so you can even view or transfer the images from the SD card into any computer. It is available at www.alarmland.com

**Holger Skurbe
Brick, NJ**

#2 I recently had a need for a video recorder to complete a low-cost home video security system. Originally, I planned to use a 'spare' PC and plug in a four channel video capture card which comes with software. However, I found a seller on eBay who offered a brand new, stand-alone four channel digital video recorder for a 'buy-it-now' price of only \$180 plus shipping. The catch was these units were sold without a hard drive.

However, it's easy to install a drive and adds less than another \$100 for a

300-500 GB device. If you already have a spare drive laying around (as I did), then there's no additional cost. The best DVR recording quality requires about 1 GB per hour of recording but that storage requirement could be reduced up to a factor of 10 by selecting a lower quality (i.e., more compression) and a reduced frame rate.

This DVR is specifically designed for video security applications and accepts up to four composite video inputs. It also has the capability to record a single audio source. The recorder can be set up to run continuously or on a seven day, hour-to-hour schedule. In addition, the DVR has built-in video motion detection capability that allows custom motion areas and sensitivity levels for each camera. Plus, the DVR will accept an external trigger to initiate recording.

A composite video output jack is provided so you can watch either the real-time video or play back previously recorded video. The recorded video can be transferred to a PC and saved as an .avi file.

This DVR is network-friendly so you can actually watch what is going on from a remote location if there is a broadband connection available. As far as I'm concerned, this affordable device packs in a lot of capability and compares well to higher-end DVRs I've seen that cost five times more.

The DVR manufacturer is AV Tech, Inc. (www.avtech.com.tw; model AVC760), and the eBay seller is kingofgadgets. This DVR, or something similar, is probably available from other sources but I didn't search any further. The unit arrived promptly and has been working just fine.

**Bob Kovacs
Barnegat, NJ**

[#09074 - September 2007]

I would like to use an old 12 inch B&W monitor (RCA connection a Dell Optiplex computer) to show text parameters using this as an EMC CNC controller only.

Can I do this? If so – how?

The old CGA standard of 25 years ago was compatible with B&W monitors. In fact, the original IBM

CGA card had an RCA composite video output which is what you are looking for. All you need is a PC with an ISA card slot and one of these old cards. Otherwise, you can buy a VGA-to-composite video converter from www.blackbox.com. These are not cheap and you will find that a new VGA monitor will cost less.

Steven Schmitt
via email

[#10073 - October 2007]

I often drive my motorcycle late at night while traffic is light. There are many traffic signals where the vehicle detection device doesn't see my bike because there is not enough iron in it to trigger the inductive loop. I have to either run the light or turn right on red.

Is there a circuit capable of generating a signal that could trigger the inductive loop detector? It needs to be 12 volts and ideally low powered so that I can wire it directly into the brake light. This will also give me the ability to pulse the circuit if necessary.

Permanent magnets don't work. I even went so far as to put a row of very strong magnets on the kickstand. I then put the kickstand down directly on the grooves in the pavement where the inductive loop was buried. It never detected my 500 pound Honda.

#1 Try the Signal Sorcerer at www.signalsorcerer.com

Matthias Kersten
Bull Valley, IL

#2 The problem with detecting a motorcycle is not the lack of metal mass, but the predominantly vertical profile. The fact that the detection field is inductive in nature does not mean that a magnet will affect it, but an ordinary piece of wire will. For a simple circuit that will trigger detection, take an eight-foot length of #8 house wire, strip the insulation back half an inch at each end, and join the ends together into a loop. You can do this by crimping the ends into a one-inch bit of quarter-inch copper tubing, or soldering the ends together with a propane torch and electrical solder.

You may also want to attach a string or light chain to the triggering loop to

make picking it up easy. To use your triggering loop, drop it onto the roadway so that it crosses a detector loop. When the loops have been cut into the roadway, the sealant used to waterproof the cuts is easily seen; for loops in new roadway, you'll have to guesstimate the placement. The triggering loop must remain on the roadway until the light changes, then just pick it up and go. If there is no traffic at the intersection, the response time should be fairly quick. We use loops like these to test detection and diagnose detector loop problems, and we have found them quite reliable. Hope this helps.

Gary Sandino
via email

#3 The signal in the detector loop is most likely in the high audio or low supersonic frequency range. When I worked as a traffic signal tech., we used a portable loop to test the sensitivity of the detector loops.

The test loop consisted of about six turns of wire wound inside of a square made of plastic pipe about four

feet on a side. The ends of the loop wires were connected to a variable resistor and a switch so that when the switch was closed, the resistor was connected across the test loop. By varying the amount of resistance, we could determine the relative sensitivity of each loop that was installed in the street.

The theory is: As the switch is closed, power is absorbed from the loop in the street and applied to the resistor. At a certain point, enough power is drawn so as to cause a detection to occur.

Your problem might be solved by building a small loop (say one foot x one foot x eight or 10 turns) and mounting it under the gear box on your bike. Don't bother with the resistor — simply use a switch to short-out the loop when you are in the field of the detector loop. You will probably have to experiment with this to get the configuration right — but it's a simple and cheap solution to a problem that I also have experienced.

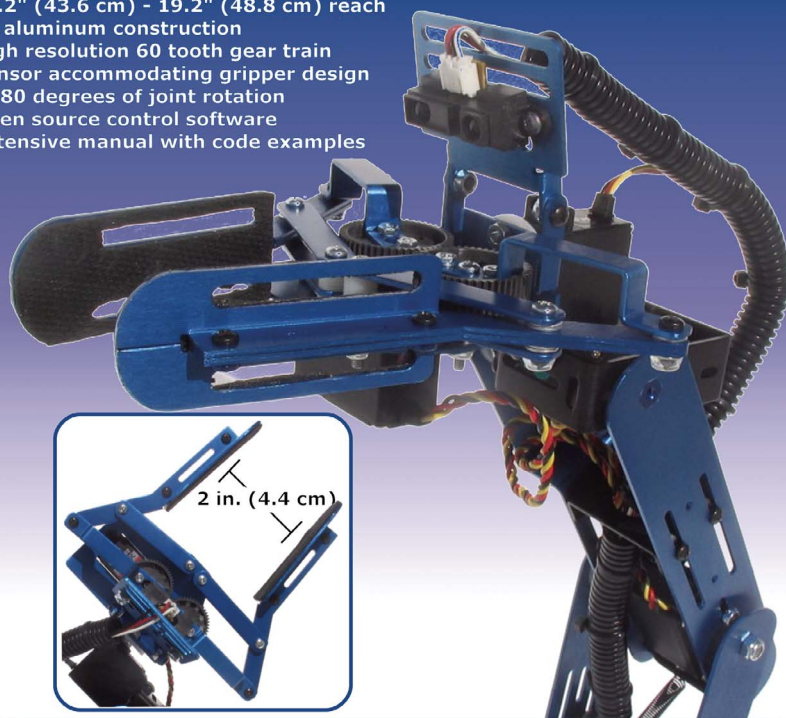
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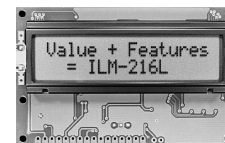
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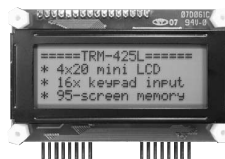
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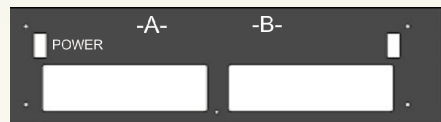
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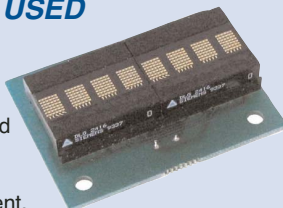
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IN THE SPOTLIGHT

An Interview with Chris Harriman of NetMedia

by Marvin Mallon

This month's spotlight is on NetMedia, Inc., a Tucson, AZ firm that has been in business since 1993. They employ 40 workers in their two facilities. The larger of the two buildings contains 18,000 square feet. A smaller unit measures some 4,000 square feet in size. They are a privately owned corporation engaged in the design and manufacturing of video distribution and camera equipment. They also make embedded microcontrol products and embedded Ethernet web components.

John "Jack" Schoof II founded the company after serving as Chairman and CEO of Artisoft, another Tucson firm. While under his supervision, that organization created numerous products including the highly successful LANTastic. This peer-to-peer networking operating system debuted in the late '80s.

We checked in recently with Chris Harriman, a member of the engineering team at NetMedia. He has been with the company for nine years. Before joining the company, he was a computer instructor in Great Falls, MT. He responded to our questions when interviewed.

Marvin: Chris, what are the names of some of your most popular products?

Chris: Our Video Products brand was introduced in 1995. It is a line of video distribution components. Included in this line of equipment are the single and TriplePlay™ modulators, CAModulators™ — the cameras with a built-in modulator, as well as our standard flush mount and indoor/outdoor cameras, available in both black and white and color.

BasicX™ is NetMedia's family of rapid development microcontrollers. It was first introduced in 1998 and includes the BasicX-01 Developer

Station and chip. The BasicX-24 Developer Station and microcontroller chip is programmed in NetMedia's version of the Basic language. The LCD+ is a backlit 4 x 20 serial LCD display, and our SRV8-T Serial Servo Board controls and provides torque feedback information for up to eight standard hobby servos

SitePlayer™ debuted in 2000. It is an embedded web server coprocessor designed for integration with virtually any serial based device. Standard HTML programming will display the host device's serial information on web pages that can be adjusted on-line from remote locations. No TCP/IP code is needed.

M: Is there a newly developed product ready for release?"

C: Yes, but at present it is under wraps and there is nothing I can reveal about it.

M: Finally, can you summarize the line of products your company manufactures, as well as the principal features of each of them?

C: As we recently stated in a press release, our built-in proprietary UTP One Wire Video technology displays bright, high contrast color video over both short and long cable lengths. It combines power and video onto one cable. It eliminates the need for dedicated power wires and nearby AC electrical outlets. Power connects to the UTP Video Decoder located at the wiring closet or distribution panel. The Decoder's composite video output connects to surveillance equipment such as digital video recorders, quad

processors, monitors, or to modulators for whole house video distribution.

NetMedia's unique UTP camera housings satisfy various installation conditions and requirements. They complement both commercial and residential environments with their sturdy, attractive enclosures. The weather resistant UTP-CAM "bullet" and UTPLAMP "flood-light" styled cameras mount directly to indoor and outdoor electrical fixtures. The inconspicuous UTPEYE "eyeball" and UTPJBOX "j-box" styled cameras mount in walls or ceilings as semi-recessed or recessed interior devices.

The UTP Camera line includes Color and Day/Night Color versions. The Day/Night Color camera features a one-third inch Sony® Super HAD CCD™, 470 lines of resolution, and infrared (IR) sensitivity. All cameras come complete with UTP video decoder, power supply, mounting hardware, and a one-year warranty.

We sell all of our products through an extensive network of national distributors. **NV**



NetMedia building.

10940 N. Stallard Pl., Tucson, AZ 85737
Tel: 520-544-4567 X102
Web: www.netmedia.com



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Item# PM-128E

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Item# PM-1028A

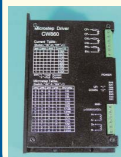
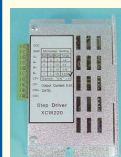
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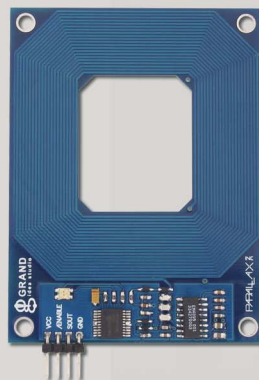
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